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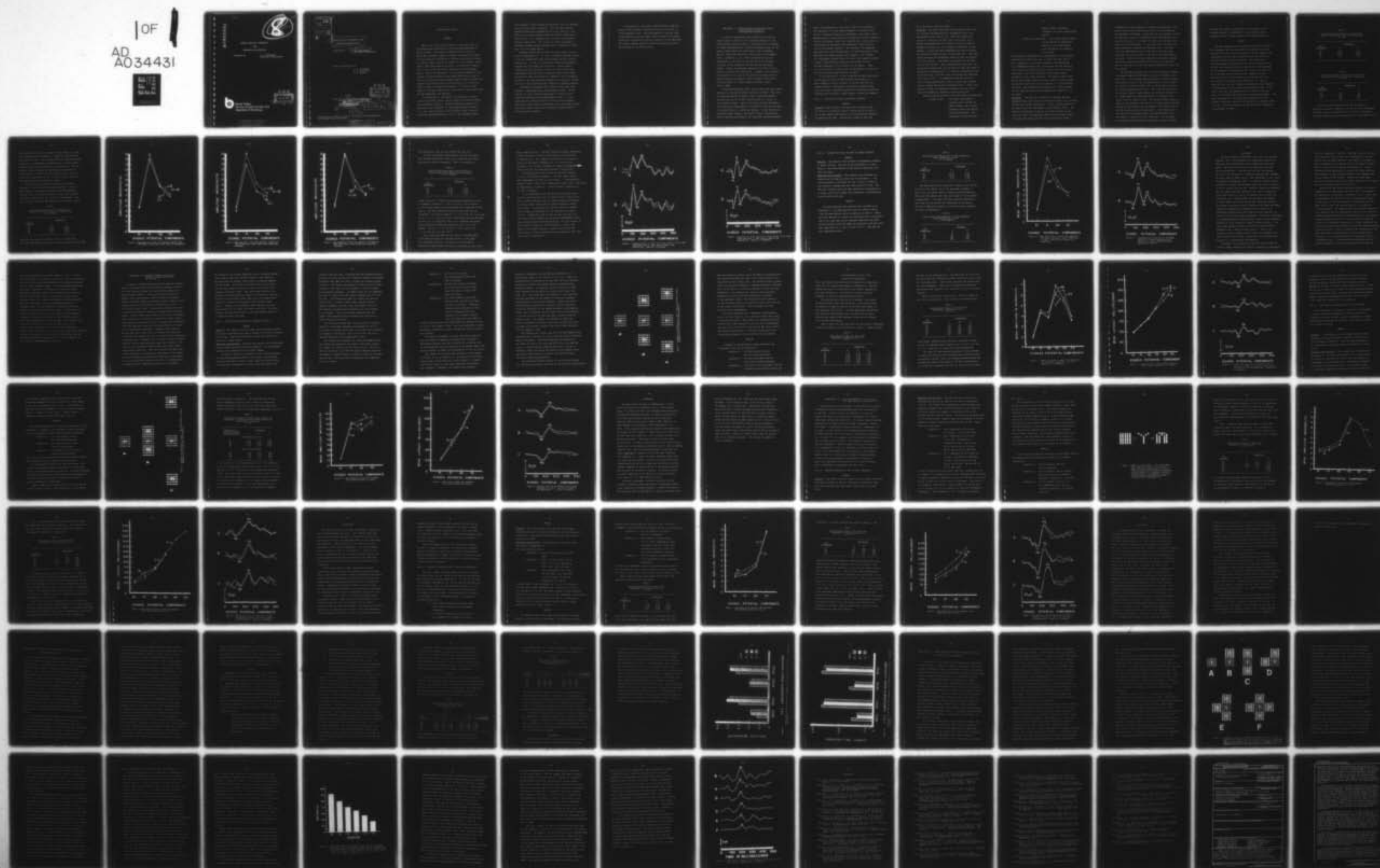

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AND

INFORMATION PROCESSING

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EVOKED CORTICAL POTENTIALS AND INFORMATION PROCESSSING.

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ABSTRACT

This is the fourth annual report to originate from the Psychophysiology Laboratory of the Psychology Department at Baruch College. The research completed over the last 12 months has included a number of studies concerned with evoked cortical potential correlates of stimulus processing in humans. The present report details the results of three separate experiments, each consisting of two parts. One portion of Experiment I (Part A) was previously reported in the 1975 Annual Report. Part B of Experiment I is a follow-up conducted in an attempt to explain apparent male-female differences found in Part A, in which the visual evoked potential (VEP) of males was enhanced with induced muscle tension (IMT) but no consistent effect on VEPs of females was observed. In Part B, a new sample of 10 female subjects was tested with a reduced IMT level and VEP enhancement was observed.

In Experiment II, the effects of contiguity of target (initial) and mask (later) visual stimuli on backward masking and the VEP was examined. Backward masking was found to be affected by the contiguity of later-appearing grid stimuli, i.e., the closer the mask to the original target, the more likely was backward masking to occur. When masking stimuli

were removed a short distance horizontally (Part A), masking still occurred in most instances. With the mask farther removed horizontally, masking did not occur (Part B). The VEPs did not differ reliably under the various conditions in either Parts A or B, possibly due to the less than optimal stimulus timing used. The effects of timing and degree of contiguity between target and mask will be examined in Experiment V of this Annual Report.

Backward masking and the VEP, with new stimuli, was the focus of Experiment III. In Part A, a single character (letter Y) and its "complement" made up the target and mask stimuli, respectively. In Part A, the subjects experienced backward masking, but VEP changes did not occur. A more complex stimulus array was designed for Part B (three Ys and three complements) and under these conditions a VEP latency delay was observed under the masking as compared to the no masking condition. The VEP delay was discussed in relation to results of prior studies indicating VEP changes with backward masking.

Experiment IV examined VEPs, from left and right hemispheres, to meaningful and non-meaningful stimuli. No differences in either response amplitudes or latencies were found for meaningful and non-meaningful stimuli. It was suggested that perhaps parietal or frontal lead placements would have yielded greater differences since they might reflect associative rather than visual responses obtained from the occipital areas examined.

In Experiment V, the visual evoked potential (VEP) was measured under stimulus conditions in which the extent of visual masking varied. Increased amounts of contour interaction between target and mask stimuli resulted in stronger masking and progressively greater decreases in VEP amplitude. The results suggest possible excitatory-inhibitory neuron interactions at the visual cortex.

Experiment I: Induced Muscle Tension and Visual Cortical Evoked Potential: A Male-Female Comparison

A series of experiments have indicated that induced muscle tension (IMT) led to an increased amplitude of the visual evoked potential (VEP) in situations where a response to visual stimulation was recorded simultaneous with the IMT (Eason, Aiken, White and Lichtenstein, 1964; Andreassi, Mayzner, Beyda and Davidovics, 1970; Dinges and Klingaman, 1972). Andreassi et. al. (1970) hypothesized that the enhancement of the VEP with IMT was due to the arousing influence of the ascending reticular activating system (ARAS). Dinges and Klingaman suggested that their results tended to support this hypothesis. A number of past studies have pointed to the role of the ARAS in producing cortical arousal (Moruzzi and Magoun, 1949; Lindsley, 1956) and in the facilitation of visual response (Lindsley, 1958; Fuster, 1958).

Landau and Buchsbaum (1973) used six male and eight female subjects in testing the effects of IMT on the VEP. They used an additional mental arithmetic task to determine whether distraction from the visual stimulus would be a factor in any observed changes. Unlike the earlier studies mentioned, they reported no enhancement of the VEP with IMT, nor was there a different effect for males and females. In the Landau and Buchsbaum study, however, the level of muscle tension used was not adjusted according to the individual subject's maximum grip. The adjustment of the level of IMT to the capacity of the individual is a well known procedure in studies of the effects of muscular tension on performance (see Courts, 1942). The importance of this procedure is emphasized by the findings of Wilcott and Beenken (1957), who reported that a given level of IMT resulted in different electromyographic (EMG) activity levels in different subjects. The difference in integrated EMG levels was noted between males, but was especially visible when male and female subjects were compared. For example, at a dynamometer squeeze level of 5 lbs., the females produced a mean of approximately 125 microvolts of EMG activity (biceps) compared to 72 microvolts for the males. Thus, it is clear that at a given level of IMT, females are likely to use more muscular energy relative to males.

In our laboratory, a pilot study had revealed differences in the effects of IMT on VEPs of males and females, i.e., males seemed to show an increase in the VEP with IMT, but females did not. The present investigation expanded upon the pilot study to determine whether this observed preliminary finding would hold with a larger sample of males and females.

Part A: IMT and VEP; Males and Females Compared

METHOD

Subjects: Twenty subjects (10 males and 10 females) with no visual or neurological defects (except myopia corrected to at least 20/25) participated in two experimental sessions separated by one week. The subjects ranged in age from

19 to 70, with a mean of 25 years.

Procedure: The pilot experiment had determined that 1/7th of a person's maximum grip on a dynamometer would be an appropriate level of IMT to use. Since the subject was required to maintain the grip level continuously over a period of approximately two minutes, a level of 1/6th of maximum was found to be too fatiguing, especially for the females. A Stoelting hand dynamometer was used to induce and record the subject's grip in kilograms (kg). Each individual squeezed the dynamometer handle as hard as possible for three seconds. (The handle was adjusted to the hand size of each person.) Three readings were taken with a 30 second rest between each, and the mean of these was taken as the person's maximum grip. If a subject's maximum grip was 28 kg (61.6 lbs.) then the level used during IMT conditions was 4 kg (8.8 lbs.). An adjustable clip was used as a "stop" during experimental trials to insure that subjects did not squeeze beyond their determined level. With a few practice trials, the subjects learned to use the stop as effective feedback to maintain a given grip level.

Evoked potential data were collected under two conditions:

A (light alone) The subject was asked to silently count a series of light flashes, and to avoid blinking his/her eyes during flash presentations. The dynamometer handle was held lightly without squeezing throughout the entire presentation period.

B (light plus squeezing) - The subject again counted, but maintained the dynamometer squeeze at the predetermined level throughout the presentation period.

The testing of each subject was accomplished in two sessions, separated by at least one week, at about the same time of day. Conditions A and B were completely counterbalanced in an ABBABAAB sequence over the two days and over subjects. Four trials were completed on the first day and four on the second day. Each trial consisted of 100 light flashes presented at one second intervals. The subjects had a three minute rest between each of the four trials to avoid fatigue and possible carry-over from a squeezing to a non-squeezing condition. The dynamometer was mounted in a wooden support so that subjects would not be burdened with balancing it on the table.

Apparatus: The EEG was recorded with a Beckman Type RM Dynograph from Grass silver cup electrodes places at O_z (active) and the left earlobe (reference). The O_z lead was placed in accordance with the "Ten-Twenty" System (Jasper, 1958). The subject was grounded by another electrode attached to the right ear lobe. Eye movements (EOG) were monitored by means of another electrode, and VEP traces suspected of being contaminated by eye movements or blinks were discarded. This rarely occurred since subjects were able to avoid excessive eye movements or blinking. Inspection for eye movement or blink contamination involved a comparison of the averaged EOG trace with the VEP trace. A straight line EOG trace indicated very little or no eye movement. A rise then dip in the EOG trace would indicate a consistent eye movement, and, if the EOG trace was superimposed over the VEP trace, the effect was noticeable by rises and dips in the VEP at the same temporal positions. This monitoring of possible eye movement contamination was carried out on-line and, in the rare instances when it occurred, the trial was repeated immediately after the rest period.

EEG and EOG potentials were fed into a Mnemotron Computer of Average Transients (CAT/1000) to produce averaged O_z and EOG traces. Five hundred millisecond (msec) duration samples were taken for each of the 100 presentations of the stimulus. At the end of each two trials, the O_z and EOG were traced out on a Hewlett-Packard X=Y Plotter. The visual stimulus was a 10 microsec flash of light produced by intensity setting "1" of a Grass Model PS-2 photostimulator at a distance of 49 inches from the subject's eyes. The photostimulator bulb was placed in an opening at the center of a black shield which was mounted in the window of an IAC Chamber. The subjects sat in the IAC Chamber during the experiment. A diffusing screen was placed on the window between the photostimulator and the subject to reduce the flash intensity. The screening of the photo flash reduced the brightness by about one-half and made the stimulus comfortable for the subject in the darkened Chamber. Presentation of each stimulus flash triggered the CAT to take samples of EEG and EOG activity.

RESULTS

The mean amplitudes and latencies for each of the major VEP components (N1, P1, N2 and P2) were computed for each condition for each of the 20 subjects. The N1 component was considered to be the first negative dip in the plot which occurred 50 msec after the stimulus. The amplitude of the N1 component was measured as the vertical distance from the VEP trace baseline to the trough of the first depression. The P1 component was measured as the vertical distance from N1 to the peak of the first positive component, N2 was measured as the vertical distance from the peak of P1 to the trough of the second major depression, etc. for P2. Latencies (or time after stimulus presentation) were measured to the midpoints of each positive and negative peak. If the "peak" was flat, and appeared more as a plateau, the mid-point of the plateau was taken as the latency measurement. The mean amplitudes for the various VEP components for each stimulus condition, across the 20 subjects, are shown in Table 1 for O_z. The mean latencies for the various VEP components are presented in Table 2.

Table 1

Mean VEP Amplitudes (μv) for Conditions A (Light Alone) and B (Light Plus Squeezing) N = 20

VEP Components	Conditions A	Conditions B
N1	4.59	4.75
P1	13.87	14.86
N2	8.67	8.89
P2	6.76	7.23

Table 2

Mean VEP Latencies (msec) for Conditions A (Light Alone) and B (Light Plus Squeezing) N = 20

VEP Components	Conditions A	Conditions B
N1	74	73
P1	115	116
N2	163	163
P2	206	207

The latency and amplitude data were subjected to analysis of variance (ANOVA) for the P1, N2 and P2 components. The model used for the ANOVA was a two-factor, fixed-model factorial design with four observations per cell (Winer, 1971).

The two main effects were Conditions (light alone vs. light plus squeezing) and Sex (males vs. females), and both were considered as fixed. The raw amplitude and latency data were subjected to a logarithmic transformation, to produce homogeniety of variance and normality of distribution. The six separate ANOVAs indicated no significant main effects or interactions: F (1/156) was less than the ratio of 3.91 needed for significance at the .05 level, in all instances. The amplitude data are plotted in Figure 1.

The data were then analyzed for males and females separately. Table 3 shows the amplitude data for the 10 male subjects, according to condition and VEP components. (Latency data will not be mentioned further since analyses indicated no differences for any type of comparison.) The data in Table 4 show the amplitude data for females. These

Table 3

Mean VEP Amplitudes (µv) for Conditions A (Light Alone) and B (Light Plus Squeezing) N = 10 Males

VEP Component	Condition A	Condition B
N1	3.98	4.74
P1	12.77	15.00
N2	7.61	9.17
P2	6.73	7.29

data were then plotted as Figures 2 and 3, respectively. The Tables and Figures show clear trends such that the male VEPS

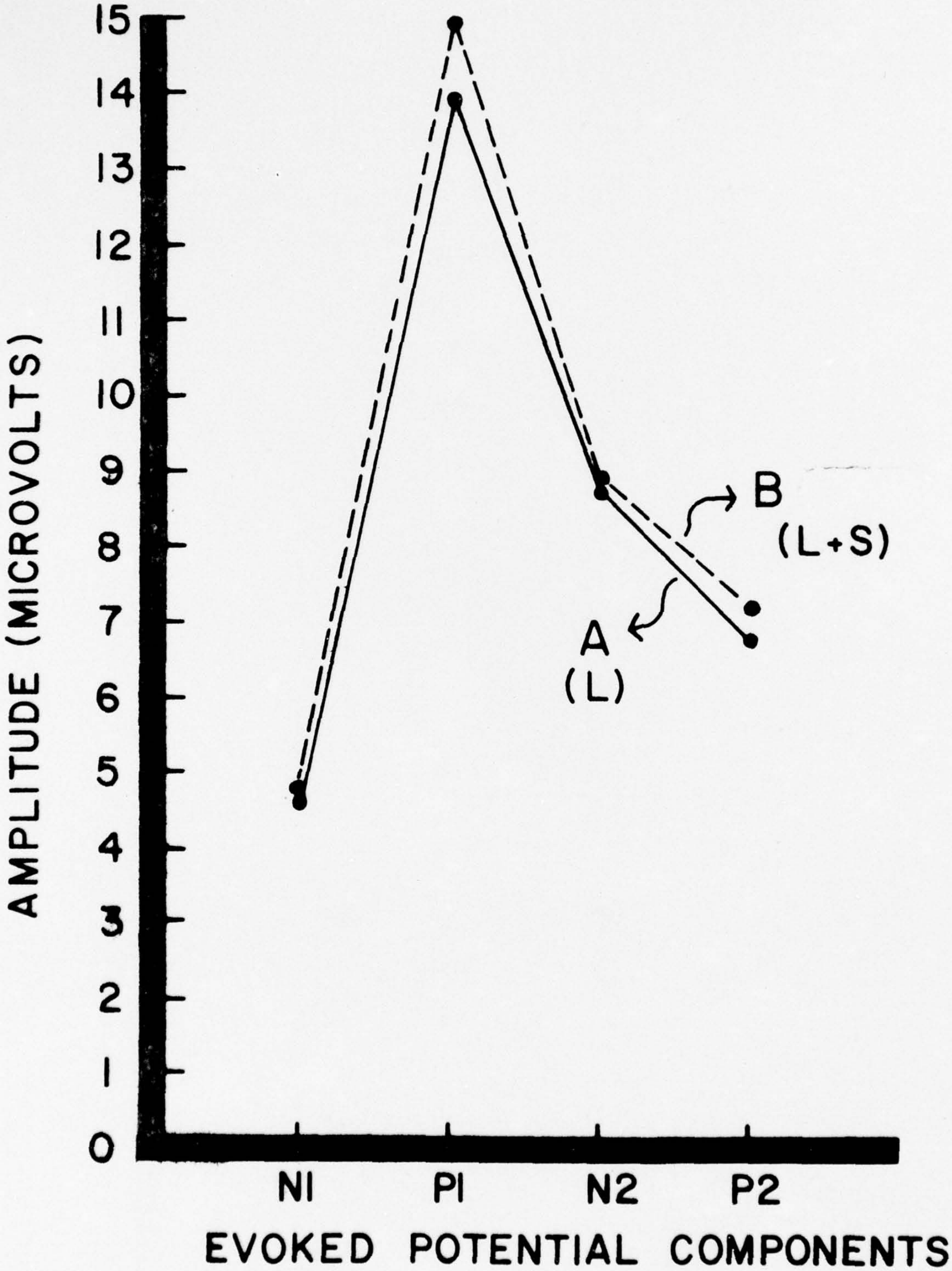

Figure 1 - Mean amplitude of major VEP components (20 Ss) under conditions A (light alone) and B (light plus squeezing).

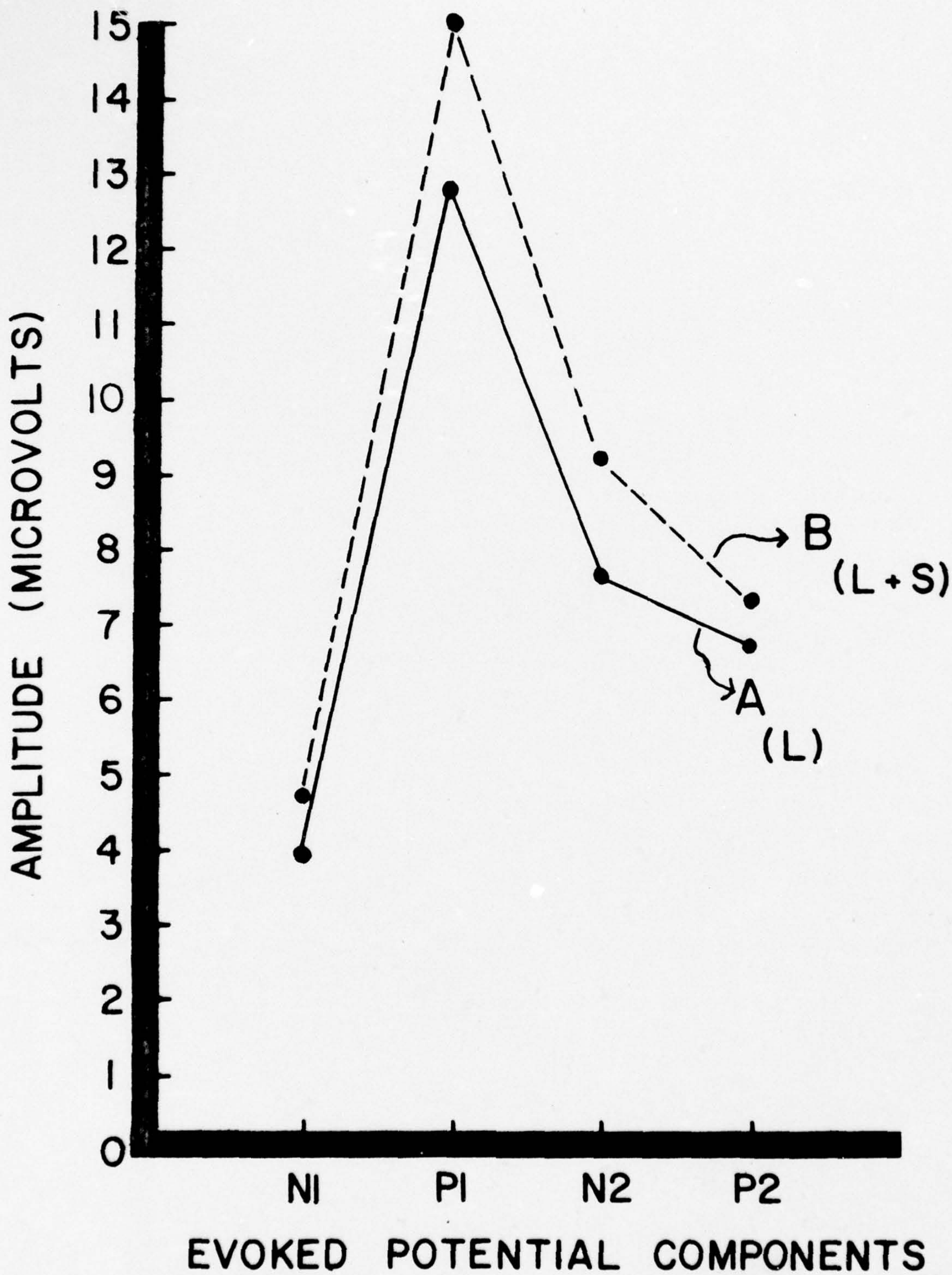

Figure 2 - Mean amplitude of major VEP components (10 male Ss) under conditions A (light alone) and B (light plus squeezing).

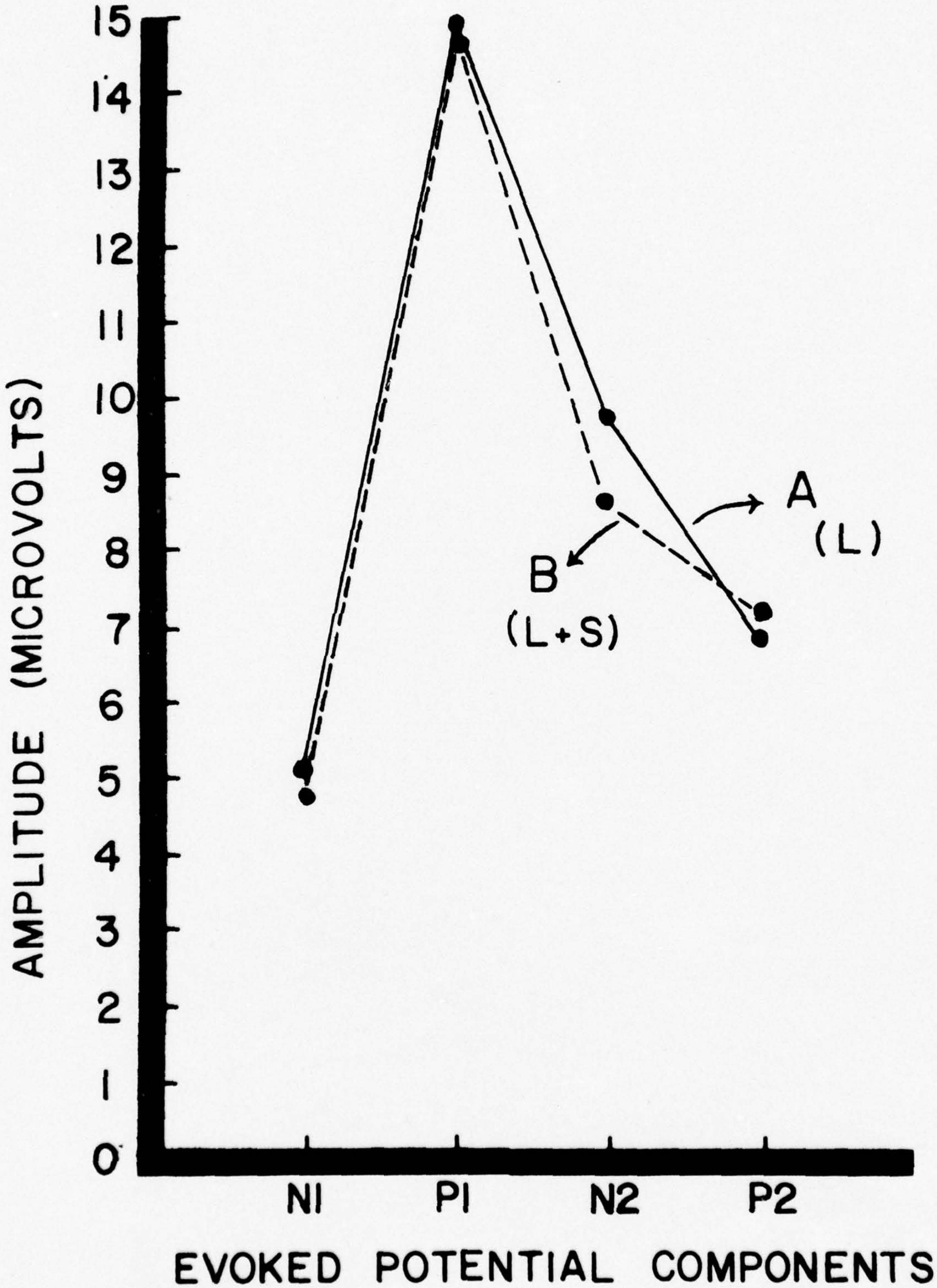

Figure 3 - Mean amplitude of major VEP components (10 female Ss) under conditions A (light alone) and B (light plus squeezing).

were enhanced by IMT, but the female VEPs were not.

To test for possible significance, the data for males were further analyzed by t-tests for correlated data using two-tailed criterion throughout. Thus, the Condition A

Table 4

Mean VEP Amplitudes (μv) for Conditions A (Light Alone) and B (Light Plus Squeezing) N = 10 Females

VEP Components	Condition A	Condition B
N1	5.13	4.76
P1	14.96	14.72
N2	9.73	8.60
P2	6.79	7.16

(light alone) vs. B (light plus squeezing) comparison for the P1 component yielded a $t = 2.87$ ($p < .02$, 9 df) in which 9 of the 10 male subjects had larger VEPs with Condition B (IMT) than A. The 10th individual had equal VEPs under the two conditions. For the N2 component, $t = 2.14$ ($p > .05$, 9 df), and for P2 $t = 1.57$ ($p > .05$, 9 df), significance was not obtained for the A vs. B comparison. None of the component amplitudes showed significant amplitude differences for A vs. B for females. For P1, $t = .67$; for N2, $t = 2.16$; and for P2, $t = .93$ (for all, $p > .05$, 9 df).

Thus, while the ANOVA did not detect a sex difference in the VEP amplitudes for the light alone vs. the light plus squeezing situation, a difference is shown when a comparison is made within the group of 10 males for one of the major components (P1). The mean difference between Conditions A and B for males' P1 was 2.23 microvolts, or an increase of 12% with IMT. This compares closely with an increase of 15% for P2 obtained by Andreassi et. al. (1970) and an increase of 12% for N2-P2 obtained by Dinges and Klingaman (1972) with four and three male subjects, respectively.

Superimposed VEP traces for one of the male subjects (J.D.S.) are depicted in Figure 4. The VEP traces clearly show enhancement with IMT for this subject. A representative sample of VEPs is shown for a female participant (Z.R.), who showed no enhancement, in Figure 5. In both figures, negativity of the VEP is downward.

It is hypothesized that the IMT task was perhaps more difficult and disruptive for the females than it was for the males. While moderate levels of IMT may improve performance in certain tasks, higher levels produce decrements (Duffy, 1957; 1962). It was noted that females tended to complain about fatigue and difficulty of the task while the males did not. Perhaps the level of IMT used was disruptive in some cases for the females and attenuated enhancement effects that otherwise might have been produced. For this reason, it was decided to conduct a second experiment, using a new group of ten female subjects, in which the level of IMT was reduced to 1/9th of maximum grip as compared to the 1/7th level used in Experiment I.

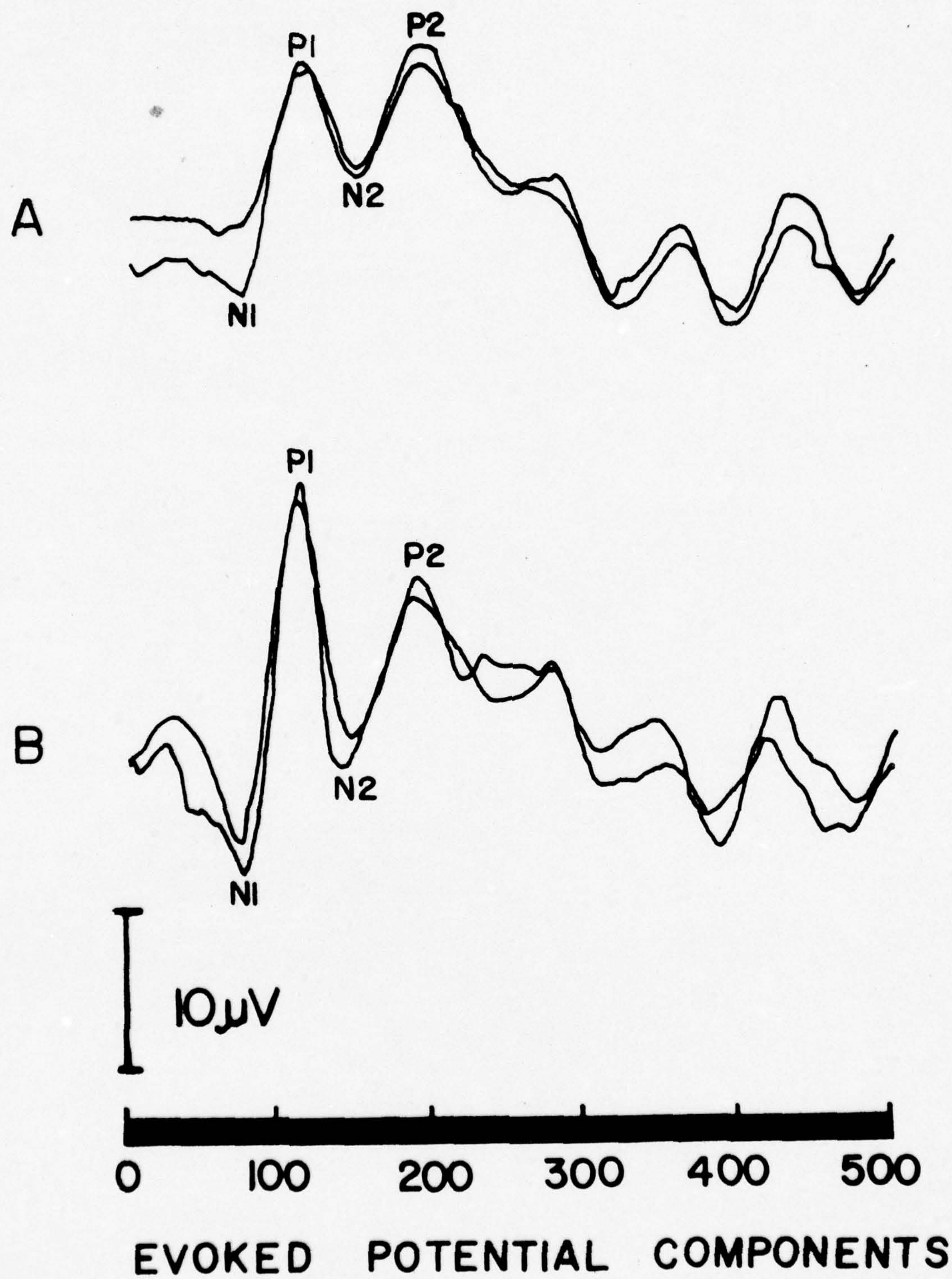

Figure 4 - Summarized VEP traces (O_z) for one male subject (J.D.S.) under Conditions **A** and B. **Each trace is based on 100 presentations. Negativity is downward.**

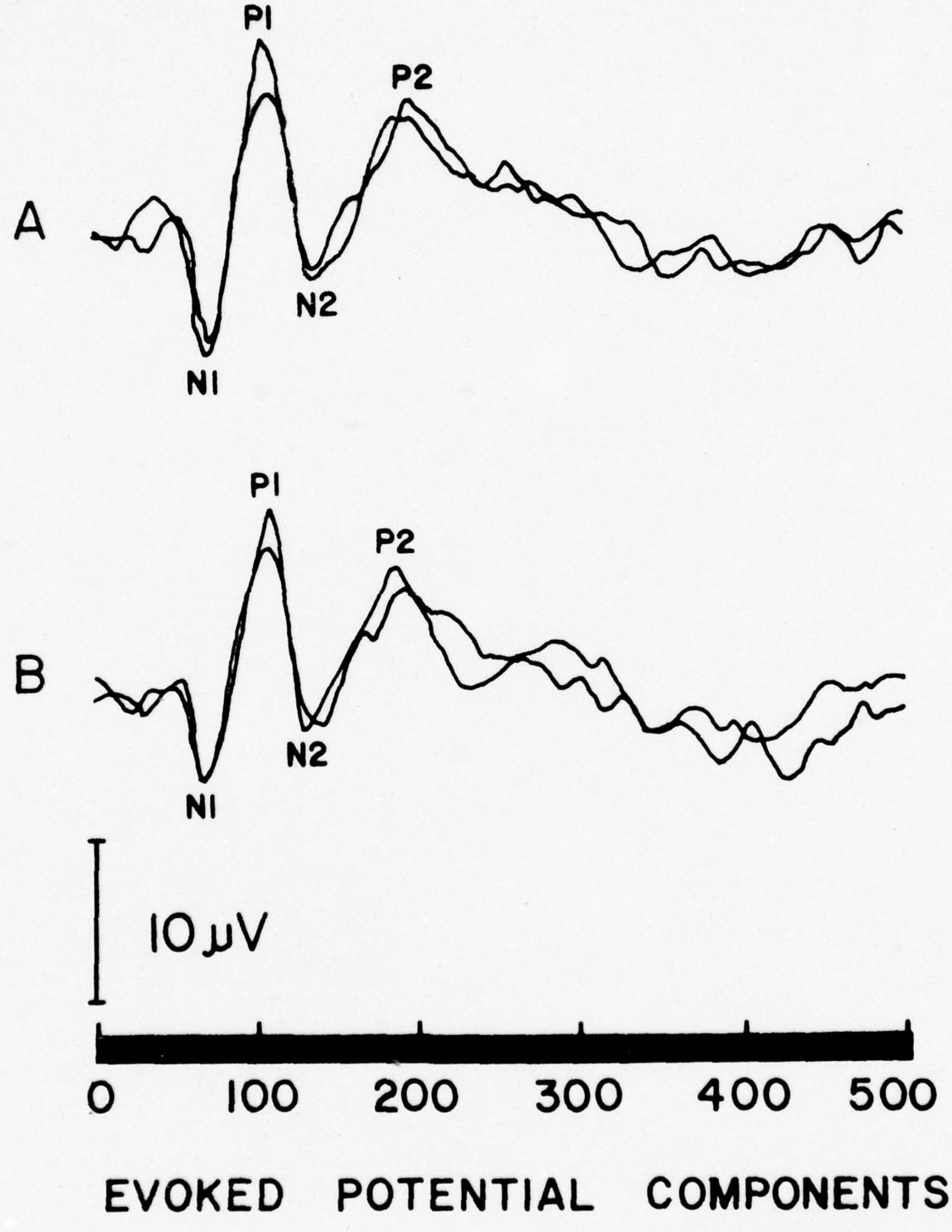

Figure 5 - Summarized VEP traces (O_z) for one female subject (Z.R.) under Conditions A and B. Each trace is based on 100 presentations. Negativity is downward.

Part B: Reduced IMT Level and VEP for Female Subjects

METHOD

Subjects: The subjects were 10 female undergraduate students at Baruch College. None had known neurological or visual defects. Each participated in two sessions separated by at least one week.

Apparatus and Procedure: The apparatus and recording procedures were the same as those used in Experiment I. The only difference in procedure was that a level of 1/9th of each subject's maximum grip was used instead of 1/7th. The VEPs were obtained under the same conditions as Experiment I: A (light alone) and B (light plus squeezing), counterbalanced across subjects and days.

RESULTS

The VEP amplitudes and latencies were obtained as in Experiment I. The mean amplitude data are shown in Table 5 and the mean latency data are presented in Table 6. These data were analyzed by t-tests for correlated data, two-tailed, and it was found that the P1 component amplitude was significantly greater under the light plus squeezing condition than with light alone ($t = 2.26$, $p < .05$, 9 d.f.). This was the only significant result.

Table 5

Mean Amplitude (Microvolts) of VEP Components
Under Conditions A and B
N = 10 Females

VEP Components	Condition A	Condition B
N1	2.10	2.36
P1	10.56	12.19
N2	6.51	7.74
P2	5.44	4.79

The amplitude data are depicted in Figure 6 and the VEP traces for one subject (E.A.) are presented in Figure 7. Nine of the ten female subjects showed increased amplitude VEPs with simultaneous IMT, the same result as for the males in Experiment I. The mean difference between Conditions A and B was 1.63 microvolts and represented an increase of 15% for P1 amplitude compared to the 12% increase obtained for males in Experiment I.

Table 6

Mean Latency (Milliseconds) of VEP Components
Under Conditions A and B
N = 10 Females

VEP Components	Condition A	Condition B
N1	82	81
P1	136	136
N2	167	170
P2	204	203

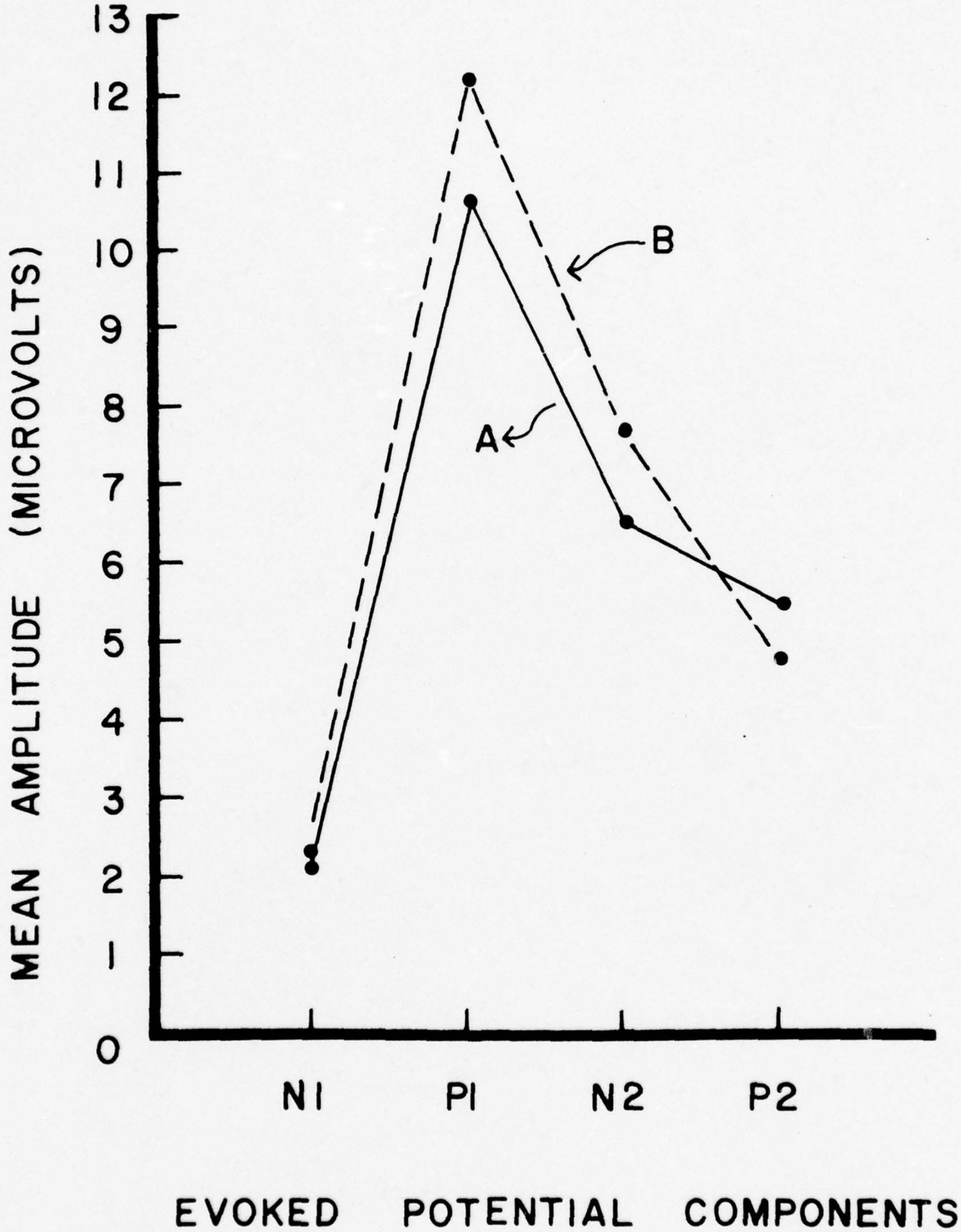

Figure 6 - Mean amplitude of major VEP components (10 female subjects) under Conditions A (light alone) and B (light plus squeezing).

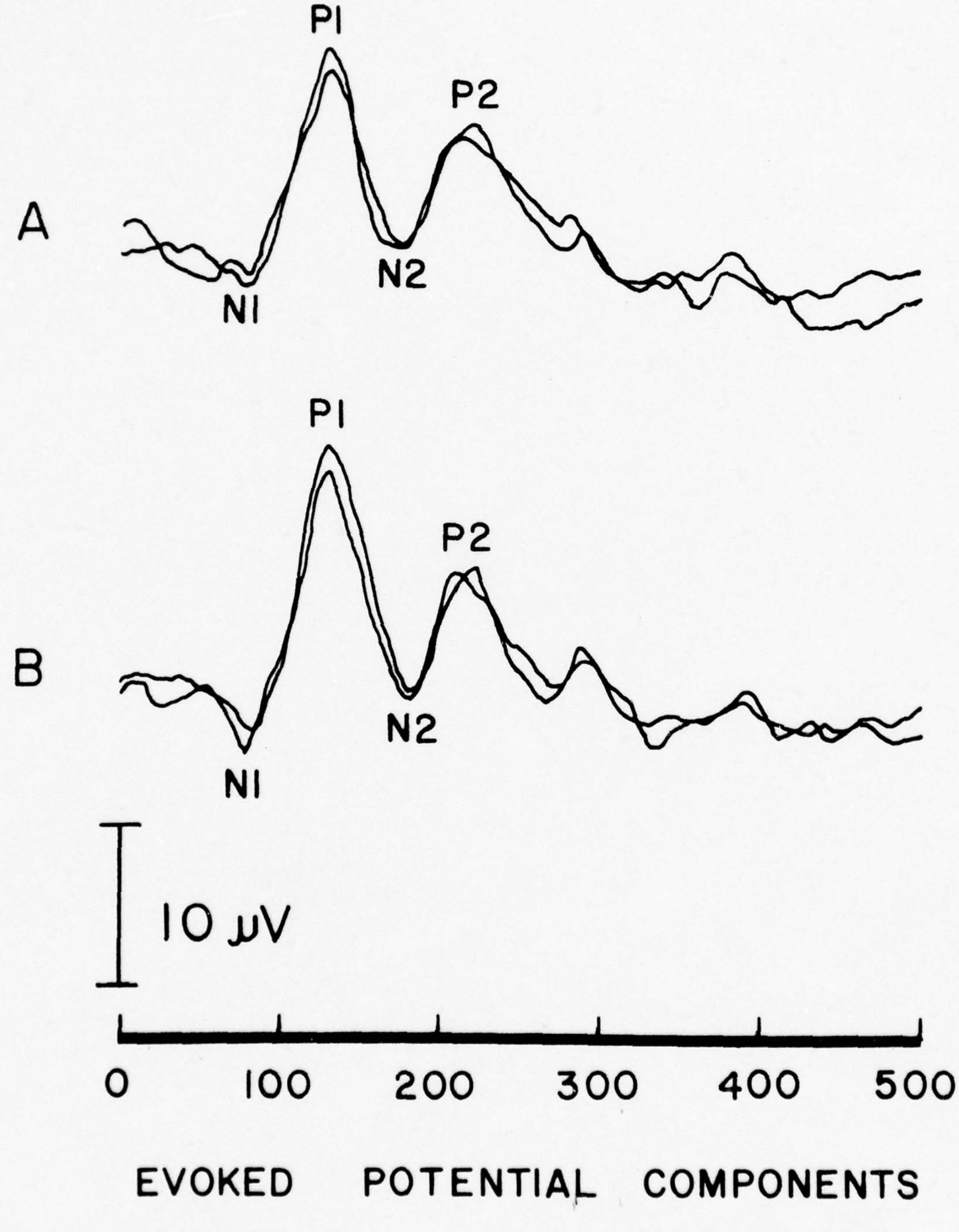

Figure 7 - Superimposed VEP traces (O_z) for one female subject (E.A.) under Conditions A and B. Each trace is based on 100 presentations. Negativity is downward.

DISCUSSION

The main finding of Experiment I was that, for the male subjects, the P1 VEP component was significantly greater in amplitude with IMT than when light flashes were presented alone. The result for P2 was in the same direction, but was not significant. This did not occur for the females. The result for the males is consistent with previous findings for male subjects (Eason et al., 1964; Andreassi, et al., 1970; and Dinges and Klingaman, 1972). It differs from the overall conclusion of Landau and Buchsbaum (1973) who found no effects of muscle tension upon the VEP. However, Landau and Buchsbaum did not analyze the data separately for their six male and eight female subjects, and it is possible that a within-sex difference, e.g., enhanced VEPs for the males, was hidden in their ANOVA, just as the within male difference found in the present experiment was not revealed in the ANOVA performed. Landau and Buchsbaum did consider sex as a factor, but differences between males and females were not observed, as they were not in the present experiment. This is not surprising in psychophysiological experimentation since a within subjects analysis is often required to detect treatment effects. The often large between subjects differences in physiological responses tend to mask treatment effects. Thus, it is possible to have treatment effects within one subgroup (e.g., males) without there being a significant effect between sub-groups (e.g., between males and females).

Experiment II indicated that when the level of IMT was reduced, female subjects also showed a significant enhancement of the P1 component of the VEP. This may be due to the fact that the higher level of IMT used in Experiment I was disruptive for the female subjects. The amount of increase in the P1 component of the VEP was 12% for the males in Experiment I and 15% for the females in Experiment II. These results show the importance of using an IMT level which has been adjusted to the individual subject's own maximum level in any studies of IMT effects. Similar VEP enhancement effects of IMT were obtained for female subjects, as for males, but at a relatively lower level of IMT.

How may the significant amplitude increase in one major component of the VEP, which occurs with IMT, be explained? We hypothesize, as previously (Andreassi, et al., 1970), that the enhancement of the VEP is due to the additional stimulating effect of IMT (proprioceptive stimulation) upon the ARAS, and, in turn, the increased effect of the ARAS on cortical activity. In expanding upon this earlier hypothesis, it is proposed that the simultaneous input via two different sensory modalities (visual and proprioceptive) to the nervous system increases the level of reticular activity and this results in an increased responsivity to visual stimulation at the level of the occipital cortex, through the thalamo-cortical projection system. There is evidence that stimulation of the ARAS can produce a physiological picture associated with alertness, i.e., desynchronization of alpha waves (Moruzzi and Magoun, 1949). It has also been established that all sensory modalities, both interoceptive and exteroceptive, give off collaterals to the ARAS (Samuels, 1959). The ARAS projects fibers to the cerebral cortex and receives projections from the cortex indicating mechanisms for interaction between the two areas (Lindsley, 1956). It has been demonstrated that electrical stimulation of the ARAS can facilitate visual perception (Lindsley, 1958; Fuster, 1958) and reaction time (Fuster, 1958; Isaac, 1960). In addition, sensory interactions between two or more simultaneously delivered stimuli have been reported to result in increased magnitude of averaged evoked cortical potentials (Gellhorn, Koella and Ballin, 1954; Andreassi and Greco, 1975). In addition, the cortical evoked potential has been reported to be enhanced during tonic arousal and attenuated with decreased activation level (Khachaturian and Gluck, 1969). The central location and connections to and from the ARAS point to its potential as a mechanism for regulating and integrating sensory input to higher levels of the central nervous system, and perhaps influencing cortical responsivity when more than one stimulus is presented simultaneously. This, we propose, is the reason for VEP enhancement with IMT.

Experiment II: Backward Masking Produced by Adjacent Stimuli and Effects on the VEP

A number of studies have obtained VEP amplitude obliteration or reduction with backward masking paradigms in which the first stimulus (target) was perceptually blanked by a second stimulus (mask). These studies include those of Donchin, Wicke and Lindsley (1963); Donchin and Lindsley (1965); and Fehmi, Adkins and Lindsley (1969) in which a very intense blanking flash completely suppressed the VEP to a less intense target flash. Metacontrast paradigms were used by Schiller and Chorover (1966) and Vaughan and Silverstein (1968). While Schiller and Chorover did not find VEP changes under conditions of metacontrast suppression (where brightness changes but intensity does not), Vaughan and Silverstein found VEP amplitude reductions with metacontrast for foveal but not parafoveal stimulation. Vaughan and Silverstein believe that the earlier failure to obtain VEP reductions by Schiller and Chorover was due to the parafoveal stimulation conditions used. Andreassi, et al. (1976, in press) obtained evidence for VEP reduction when targets were bounded on two sides by later presented stimuli, and target stimuli were perceptually suppressed. They also reported that when mask stimuli differed in configuration from targets, the targets were not perceptually suppressed and VEP was not attenuated. In all the experiments mentioned thus far, the masks either overlapped or were immediately adjacent to the targets.

The purpose of the present experiment was to determine whether later stimuli, when they bounded targets on two sides and when horizontally removed, would result in backward masking and VEP change. Definitions of several terms in accordance with current practice would be in order at this point (for example, see Turvey, 1973). The term Target refers to the stimulus or stimuli which the subject is required to identify. The Mask is the stimulus which comes after the Target and is expected to change the perception of the Target in some manner. Stimulus onset asychrony (SOA) indicates the time between onset of the Target and onset of the Mask. The inter-stimulus interval (ISI) refers to the time between offset of a Target and onset of a Mask.

Part A: Mask Stimuli Adjacent and Slightly Removed.

METHOD

Subjects: The subjects were four male and five female students and faculty associated with Baruch College of the City University of New York. None had visual defects other than myopia (corrected to at least 20/30).

Apparatus and Procedure: Subjects were seated in an electrically shielded sound-attenuated room (IAC Chamber). All experimental sessions were conducted with the lights dimmed.

In order to obtain the averaged cortical evoked potential, the electroencephalogram (EEG) of each subject was recorded from O_z ("Ten-Twenty" System, Jasper, 1958) with Grass silver cup electrodes referenced to a silver clip electrode on the subject's left ear lobe. A Beckman Type RM Dynograph Recorder was used to record the EEG and a Mnemotron Computer of Averaged Transients (CAT 1000) was used to obtain the averaged evoked potential. The subject was grounded by means of an electrode attached to the right ear lobe leading to "patient ground" of the Beckman Dynograph. The 9806A coupler of the Dynograph was used to condition the EEG signal (bandpass set at 0.5 to 32.0 Hz). The filtered and amplified signal was then fed into the CAT. A "start" signal from a PDP-8/E digital computer triggered the CAT to take EEG samples every 0.5 msec duration following the presentation of each stimulus to the subject. After 100 stimulus presentations, the summated VEP responses from CAT memory were plotted by a Hewlett-Packard X-Y Plotter.

The electro-oculogram (EOG) was measured by a separate channel of the Beckman Dynograph and averaged by the CAT as a check on possible distortions of the VEP due to excessive eye movement or eye blink. None of the trials had to be repeated because of VEP contamination by EOG.

The stimuli were displayed on a Digital Equipment Corp. VR-14 which was mounted at the subject's eye level outside the chamber at a distance of 39 inches (99 cm). The VR-14 CRT was controlled by the PDP-8/E digital computer which was programmed to deliver stimuli at specific times and locations upon the CRT. There were three conditions, each comprised of (5 x 7) Grids:

Condition A - One Grid on the screen for 20 milliseconds (msec) (ON time of 20 msec)

Condition B - One Grid for 20 msec, followed by two additional Grids 60 msec later (ON time of 20 msec, OFF time of 60 msec)

Condition C - One Grid followed by two Grids 60 msec later (ON time of 20 msec, OFF time of 60 msec). Condition C differed from Condition B in that the two following Grids were spatially at a greater distance from the center Grid (See Table 1).

In every instance there was always 1000 msec between each set of stimuli. For example, Grids 1 and 2 were presented in rapid succession, followed by a pause of 1000 msec before the next set of Grids.

The spatial arrangement in which the stimuli appeared upon the screen is represented schematically in Figure 1. The numbers indicate the order in which the successive sets of Grids appeared, and the locations of the numbers depict the actual location of stimuli as they appeared on the CRT screen.

The single .95 cm square grid produced a visual angle of 33 min. of arc in Condition A. In Condition B, the horizontal array of grids produced a visual angle of 2 degrees and 23 min., while in C the angle subtended horizontally was 3 degrees. Therefore, the stimuli were presented foveally in Condition B and partially parafoveally in C, since foveal extent is 2.5 degrees (Ruch, et. al., 1966). The characteristics of the VR-14 are such that the total luminous intensity is equally distributed among all simultaneously presented stimuli. For example, one Grid produces the same total intensity on the CRT as two Grids, three Grids, four Grids, etc. This means that the intensity of the individual character decreases as the number of characters displayed simultaneously on the screen increases. However, we used a technique which equalized the intensity of the individual characters regardless of the number presented simultaneously. Simply, extra characters (in this case, Grids) were presented on the CRT in such a way that they were concealed from the subject's view. For example, in Condition B, where one Grid is followed by two Grids, there were actually two Grids presented in the first instance, with one of them concealed from the subject's view.

The intensity of a single Grid was 5.50 millilamberts (mL) measured from a distance of 2.54 cm (one inch) with a Tektronix Digital Photometer. The stimuli appeared in locations at the center of the 7" (17.8 cm) high by 9" (22.9 cm) wide CRT screen. A small luminous fixation point 1/8" (.32 cm) in diameter, placed 1/2" above the center of the stimulus array, was used to give subjects a position upon which to focus their eyes between presentations.

The instructions asked subjects to focus directly below the fixation point between and prior to the start of presentations.

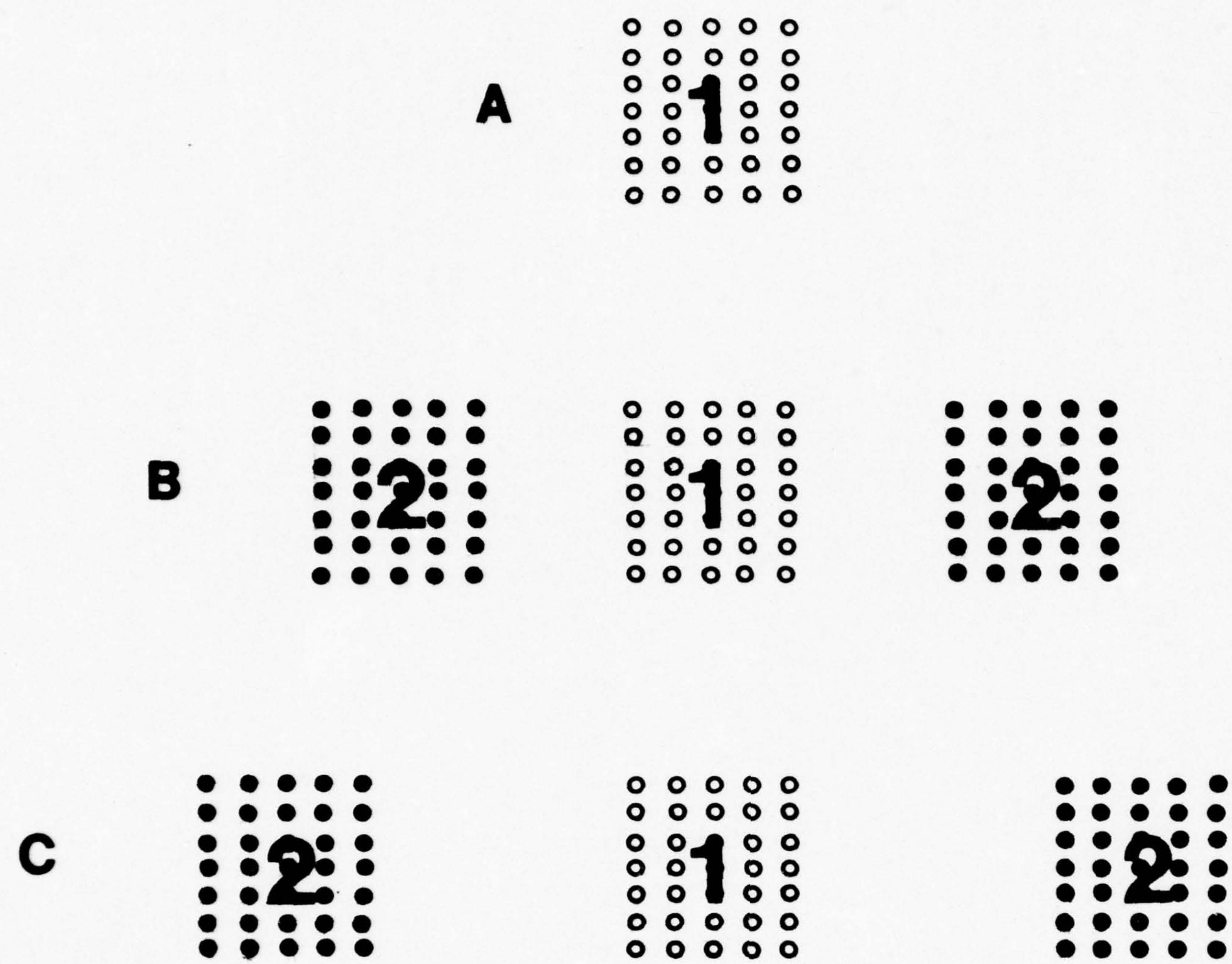

Figure 1 - Schematic of Conditions A, B and C. The grids labled 2 always appeared later in time than those labeled 1.

They were asked to silently count the number of presentations. The counting procedure was used to help insure subject concentration in this tedious task. The recording from O_z should cancel the possible influence of language functions (counting) upon the VEP since it is over the juncture of left and right hemispheres. The subjects were asked to avoid excessive movement or eye blink during presentations of stimuli. In the experiment proper, 100 presentations were given at the end of which subjects were asked to report what they saw in any single presentation. These responses were then recorded by the experimenter.

The three conditions were completely counterbalanced across the nine subjects, over a period of three days using a Latin-Square design. Each subject was presented with each condition six times during the course of three experimental sessions, for a total of 18 trials and 18 VEP traces from O_z. This method proved useful in reducing fatigue while also increasing the amount of data collected on each subject.

RESULTS

A summary of the perceptual reports indicates the following for each of the Conditions:

Condition A - All nine subjects saw one Grid (one Grid presented)

Condition B - All nine individuals saw two Grids (three Grids presented)

Condition C - Six persons saw three Grids, two saw alternately two and three Grids, and

one individual saw two Grids
(three Grids presented)

Thus, all subjects saw what would be expected in Condition A, while they all experienced masking in Condition B. Partial masking was noted for two subjects and complete masking for one under Condition C. Six subjects saw three Grids in Condition C, while the remaining three did not.

The question which now arises is whether or not these perceptual effects have VEP correlates. This question must be answered through an analysis of the VEPs with respect to both amplitude and latency. The mean amplitudes (microvolts) and latencies (milliseconds) were obtained for the major positive and negative VEP components from the X-Y tracings as in previous experiments.

Table 1 shows the mean amplitudes for the various components, across nine subjects, for Conditions A, B and C. Figure 2 shows

Table 1

Mean Amplitude (μv) for Major VEP Components, Conditions A, B, C
N = 9

VEP Component	Conditions A	B	C
N1	2.18	1.88	1.99
P1	4.24	4.54	4.30
N2	3.86	3.78	4.35
P2	6.25	6.90	6.08
N3	6.47	5.65	5.41
P3	3.54	3.94	3.63

the plot of the amplitude data. The amplitudes of P1, N2 and P2 were tested for differences between conditions using t-tests for correlated data. A two-tailed criterion for significance was used throughout. There were no significant amplitude differences with respect to P1, N2 and P2 for any of the comparisons.

Table 2 contains the latency data. Figure 3 shows the plot of the latency data. The t-tests for correlated data

Table 2

Mean Latencies (msec) for Major VEP
Components, Conditions A, B, C
N = 9

VEP	Conditions		
Component	A	B	C
N1	96	96	97
P1	131	131	130
N2	163	161	166
P2	214	209	214
N3	278	249	274
P3	318	294	312

(two-tailed) indicated that Condition A produced a longer latency P2 component when compared to B ($t = 2.42$, $p < .05$, $df = 8$). There were no other significant comparisons.

The condition which produced masking (B) also resulted in shorter P2 latencies than obtained under conditions where no masking occurred. Thus, even though backward masking was obtained for 100% of the subjects, the VEP correlates were not clear. One possibility is that the second set of stimuli

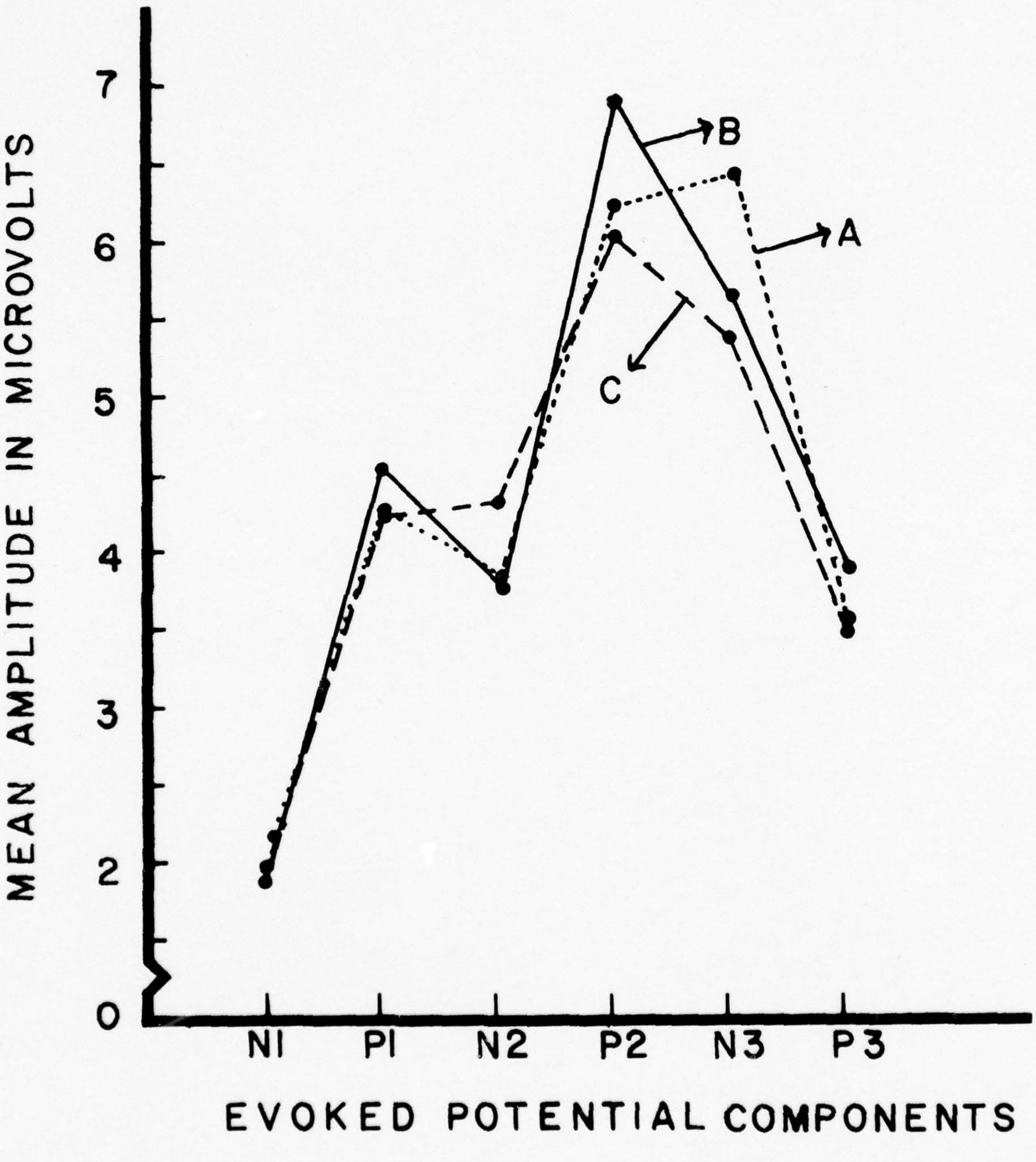

Figure 2 - Mean amplitude of major VEP components (9 Ss) under Conditions A, B and C. Negativity is downward.

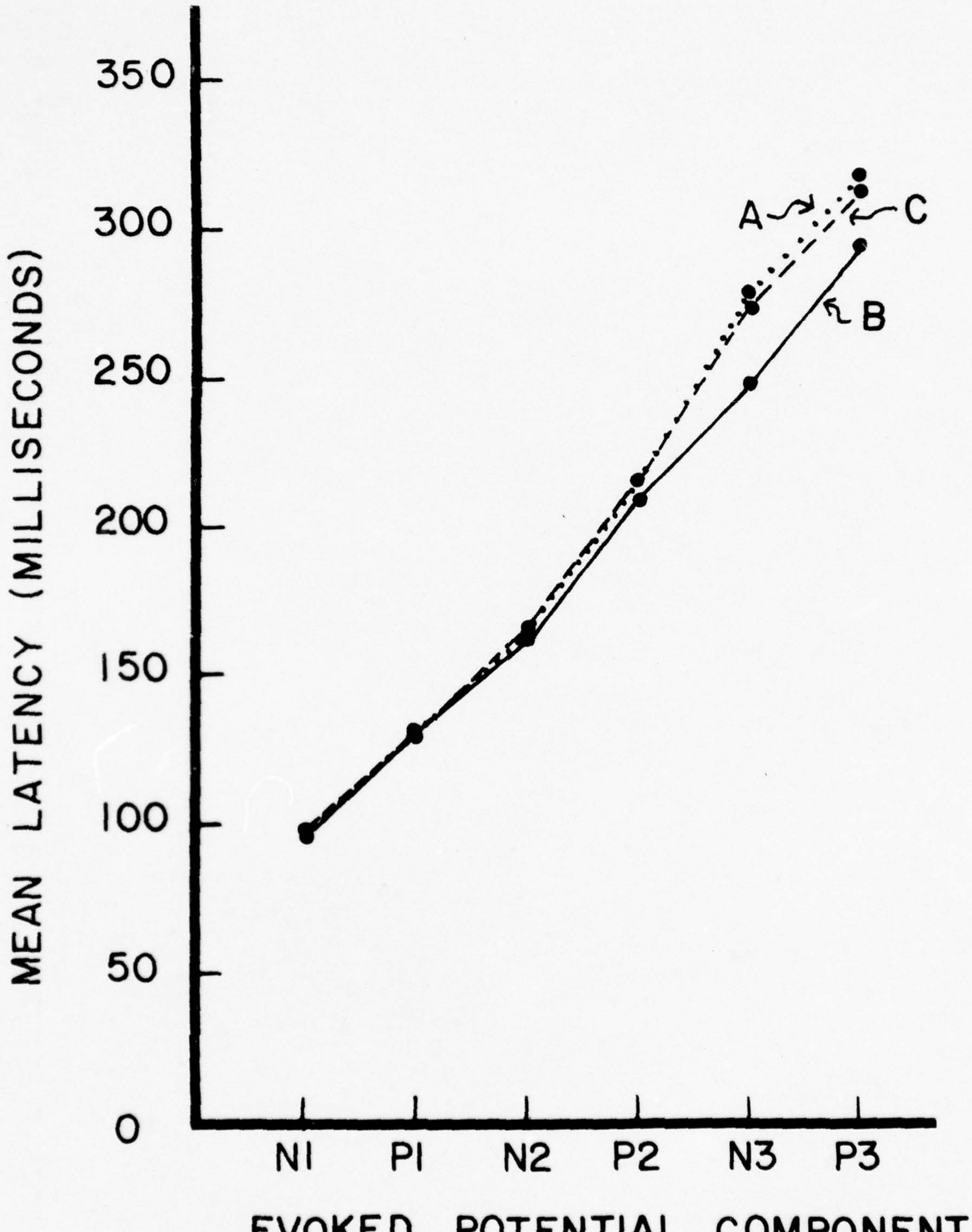

Figure 3 - Mean latency of major VEP components (9 Ss) under Conditions A, B and C.

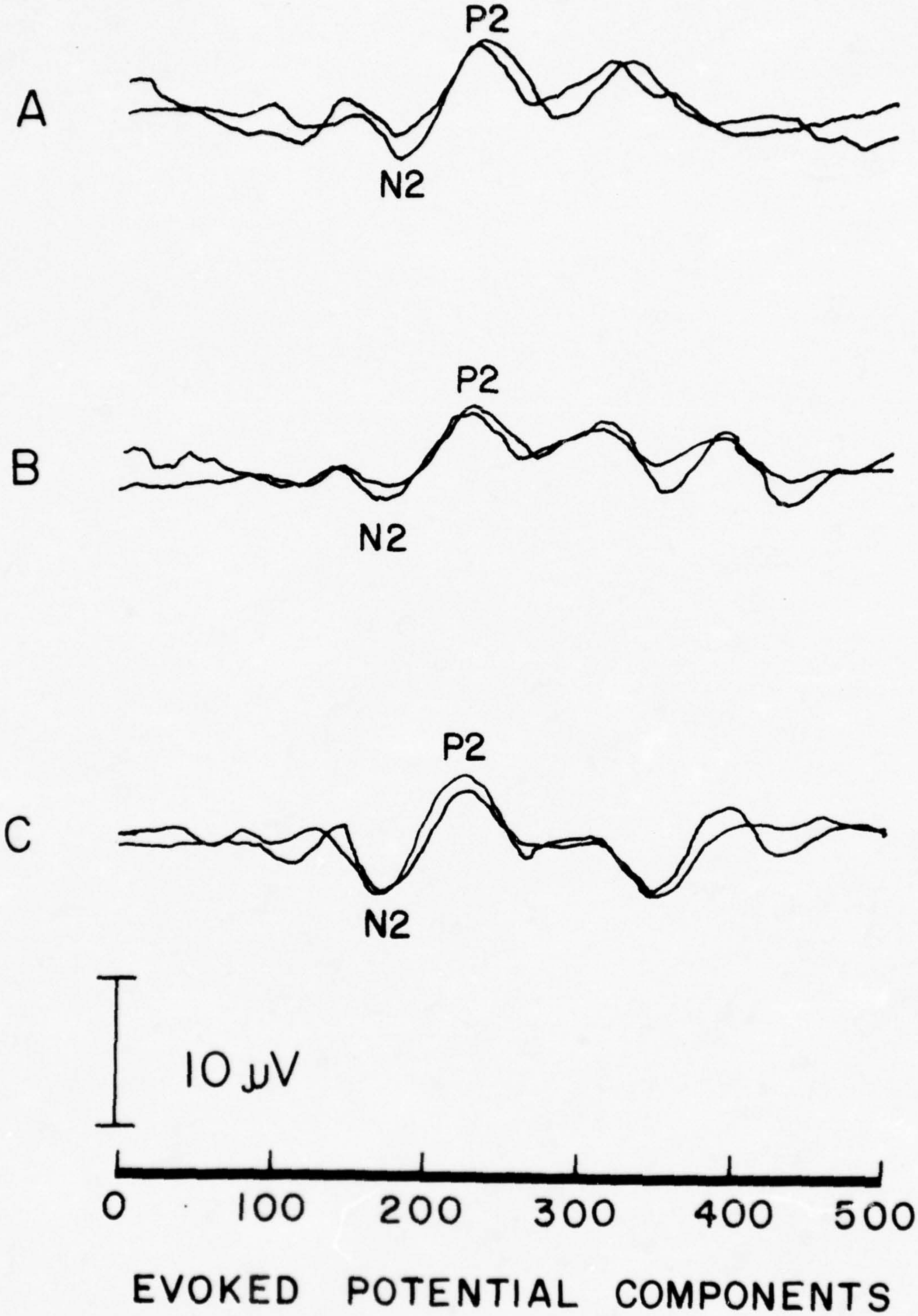

Figure 4 - Raw traces (O_z) for one subject (J.M.) under Conditions A, B and C. Each trace is based on 100 presentations. Negativity is downward.

in Condition B were too far removed in time from the first stimulus to affect the VEP amplitude or latency adversely. The SOA was 80 msec between the first and second stimulus compared to 60 msec in earlier studies (Andreassi et al., 1976). The delay was obviously not enough to prevent backward masking, but may have been too great to produce VEP amplitude decreases. Figure 4 shows the superimposed VEP traces for one subject (J.M.) under the condition of this experiment.

Part B: Mask Stimuli Overlapping and Farther Removed

This experiment is basically a replication of Experiment I, using a different arrangement of the Grid stimuli to determine the extent to which spatial arrangement of stimuli affected the perception of, and VEPs to the initial stimulus in a series of stimuli.

METHOD

Subjects: The subjects were four female and five males students and faculty associated with Baruch College of the City University of New York. None had known neurological or visual defects other than myopia (corrected to at least 20/30).

Apparatus and Procedure: The procedure was the same as in Experiment I. The timing and sequence of the presentation of stimuli for Conditions A, B and C were the same as in Experiment I with the exception of the spatial arrangement of stimuli for Conditions B and C. The second two grids in Condition B spatially overlapped the initial stimulus by

.4 cm and at a distance of 99 cm (39 inches), the outer horizontal dimension (2.45 cm) resulted in a visual angle at the eye of 1 degree, 28 min. of arc. In Condition C, the outer horizontal dimension (7.25 cm) produced a visual angle of 4 degrees, 11 min. of arc. Figure 5 shows a schematic of the three conditions used in Part B.

RESULTS

Did backward masking occur under the conditions of this experiment? A summary of the perceptual reports indicated that the following were seen under the three conditions:

Condition A - All nine subjects saw one Grid (one Grid presented)

Condition B - All subjects saw two Grids (three Grids presented)

Condition C - All subjects saw three Grids (three Grids presented)

Thus, the reports indicated that there was complete masking under Condition B and no masking under Condition C.

Do the perceptual effects have VEP correlates? This question is answered through an analysis of the VEPs with respect to both amplitudes and latencies. The mean amplitudes (microvolts) and latencies (milliseconds) were obtained for the major positive and negative components from the X-Y plotter tracings as in Experiment I.

Table 3 shows the mean amplitudes for the various components, across subjects, for Conditions A, B and C which

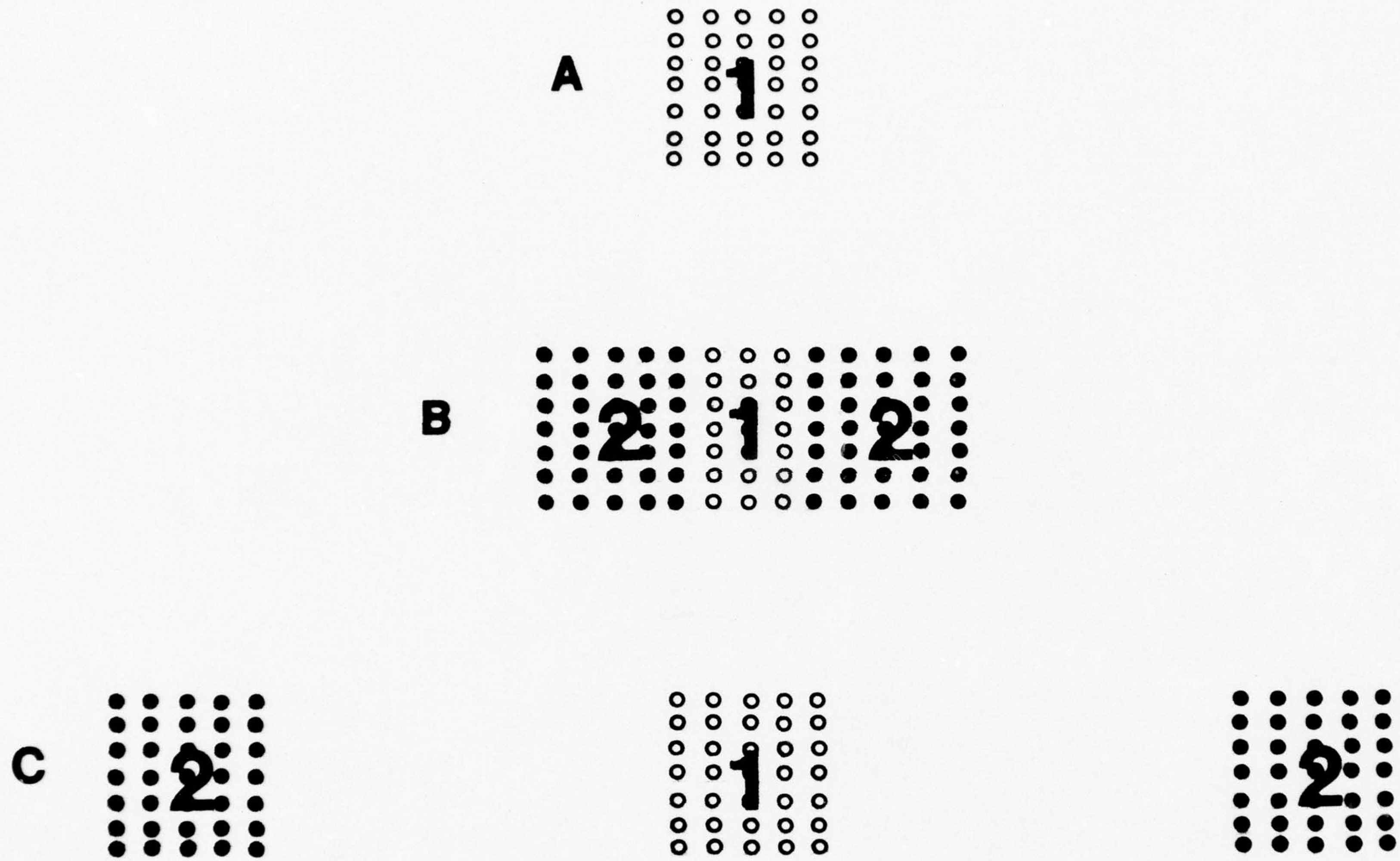

Figure 5 - Schematic of Conditions A, B and C. The grids labeled 2 always appeared later in time than those labeled 1.

are illustrated in Figure 6. The amplitudes for the two major components, N2 and P2, were tested for differences between conditions using t-tests for correlated data (two-tailed criterion). None of the amplitude comparisons, A vs. B,

Table 3

Mean Amplitude (μV) and Mean Latency (msec) of Components of Visual Cortical Evoked Potentials Under Three Conditions
N = 9

Component of Visual Cortical Evoked Potential	Condition A	Condition B	Condition C
	Mean Amplitude (uV)		
N1	1.73	1.72	1.62
P2	4.58	5.15	4.93
N2	4.37	4.48	5.39
P2	4.93	5.27	5.66
	Mean Latency (msec)		
N1	101	102	101
P1	136	143	136
N2	176	177	180
P2	227	229	234

A vs. C and B vs. C were significant for P2. For Condition C, the N2 component was significantly larger than A ($t = 2.35$, $p < .05$, $df = 8$). This was the only significant difference found. The latency data are also presented in Table 3. There was no significant latency difference with respect to N2 and P2 for any of the comparisons. The latency data from Table 3 are illustrated in Figure 7. The superimposed VEP traces for one of the subjects (J.L.A.) are depicted in Figure 8.

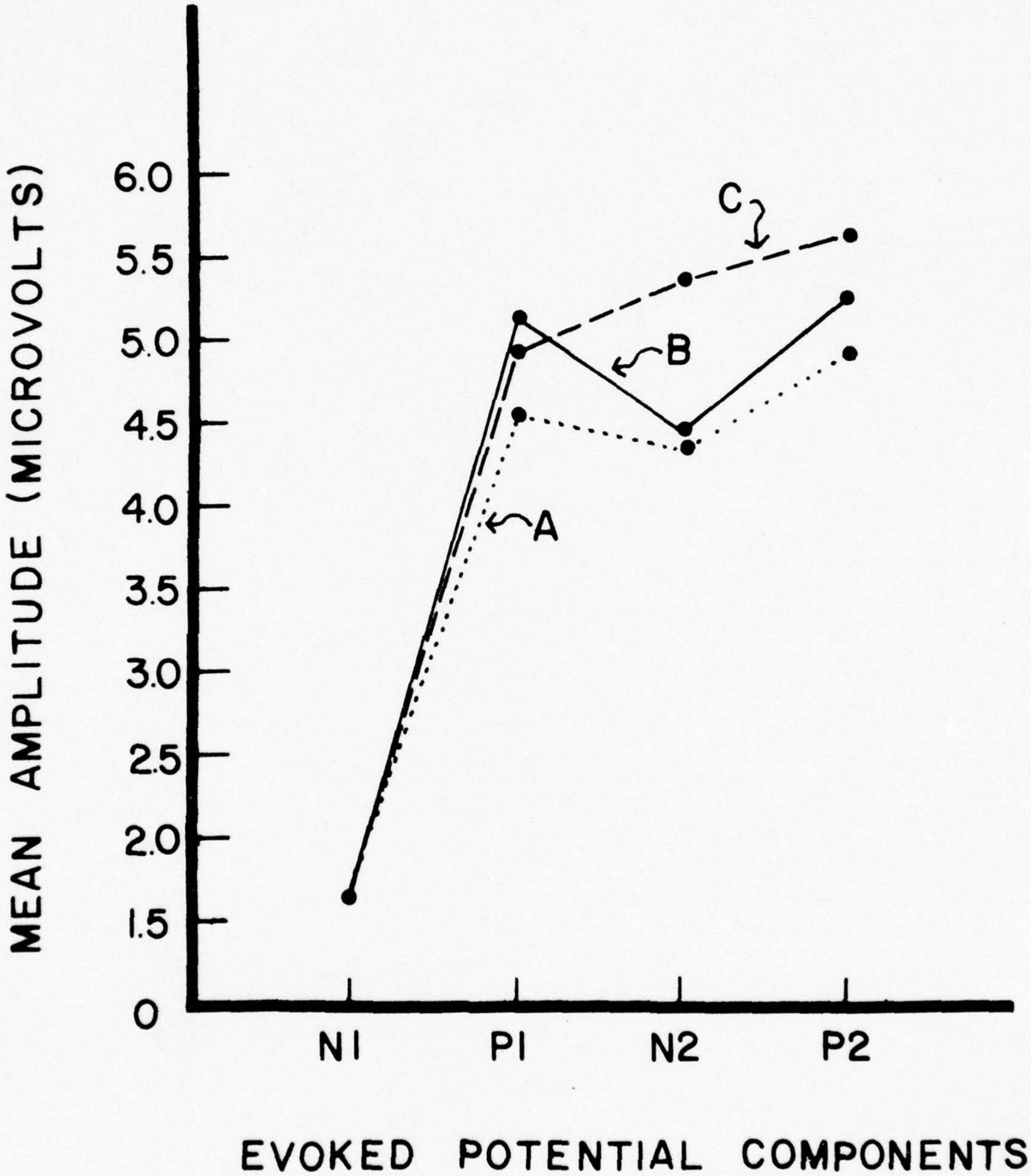

Figure 6 - Mean amplitude of major VEP components (9 Ss) under Conditions A, B and C.

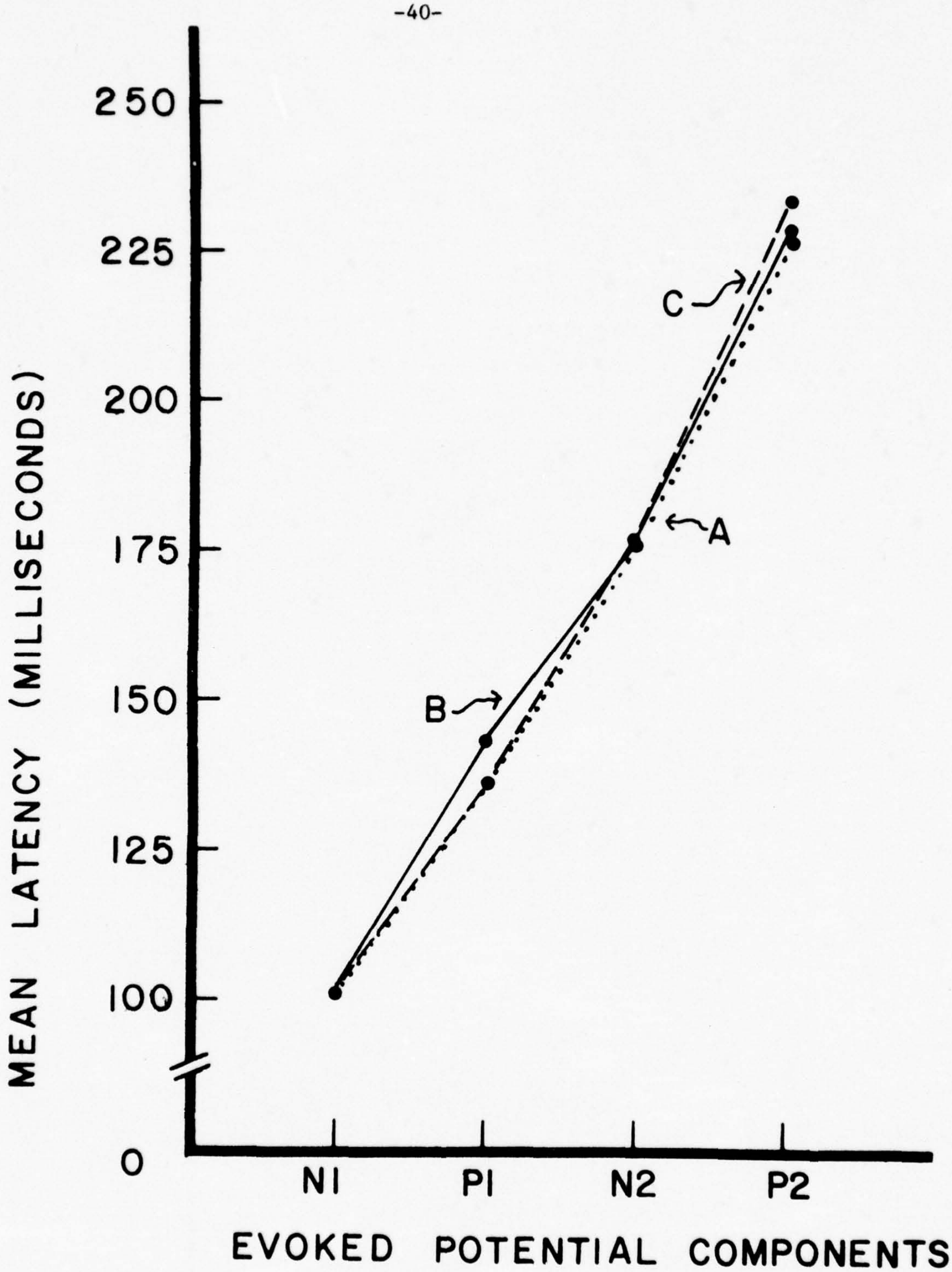

Figure 7 - Mean latency of major VEP components (9 Ss) under Conditions A, B and C.

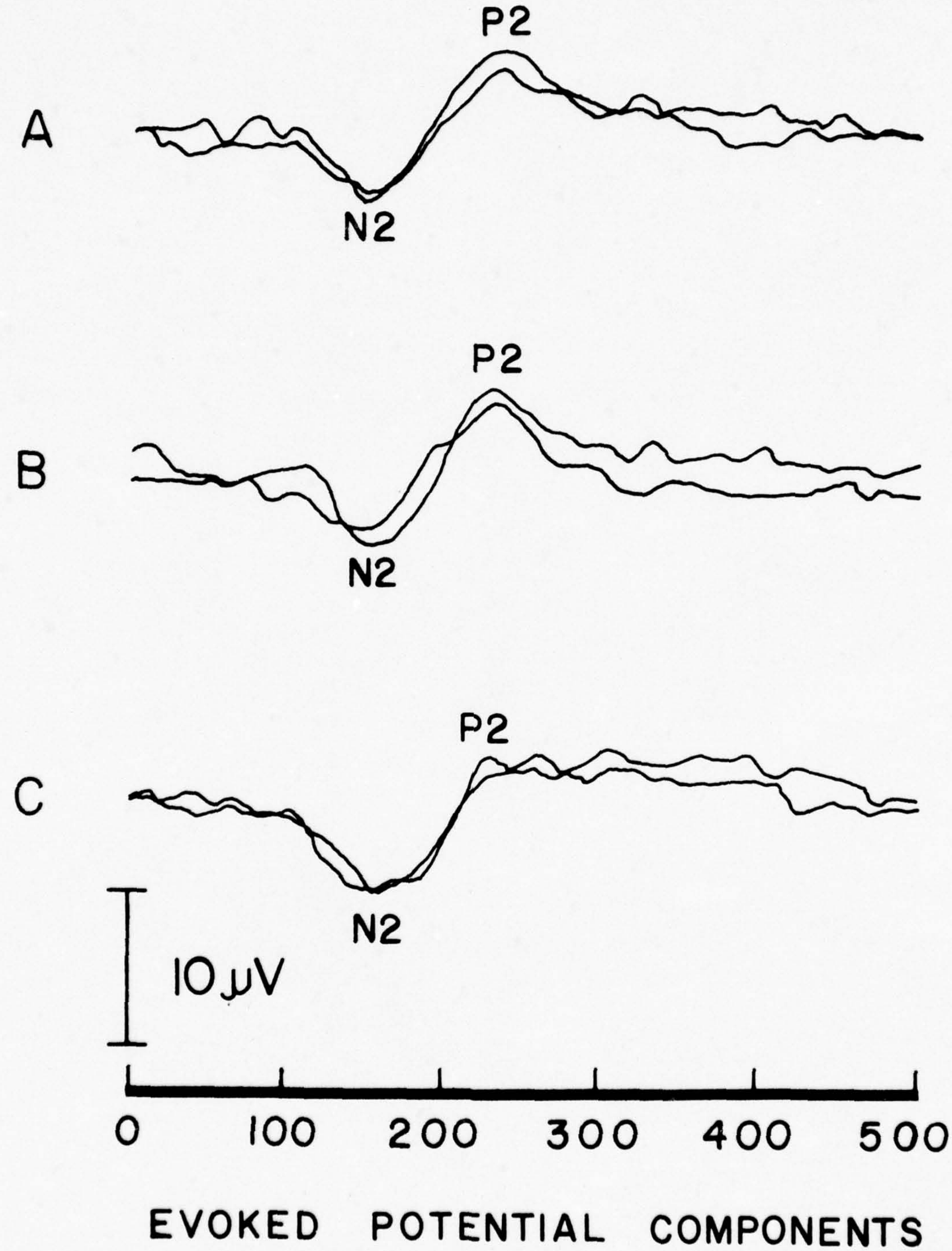

Figure 8 - Raw traces (O_z) for one subject (J.L.A.) under Conditions A, B and C. Each trace is based on 100 presentations. Negativity is downward.

DISCUSSION

The main result for Part A of Experiment II is the shorter P2 latency for Condition B vs. A. This latency result is inconsistent with past findings which have mainly involved VEP amplitude decreases or complete obliteration of the VEP with backward masking (Donchin, Wicke and Lindsley, 1963); Donchin and Lindsley, 1965; Fehmi et. al, 1969; Vaughan and Silverstein, 1968; Andreassi et. al., 1976). Since backward masking was obtained with Condition B, it perhaps would be logical to expect some interference with the VEP under this condition, i.e., a latency increase or an amplitude decrease. The results of Part B do not clear up the matter. In Part B, the latencies do not differ at all between the two non-masking conditions A and C, and the masking condition (B). The only difference which occurred was the larger amplitude N2 component of the VEP under Condition C as compared to A. These were both conditions under which the target was not masked. Condition C may have been more attention-getting since the target was followed by two other stimuli, compared to target only in A, and perhaps produced more interest on the part of subjects. Attention is known to enhance amplitude of the VEP (e.g., Donchin and Cohen, 1967; Eason et. al., 1969; Musicant, 1975).

Therefore, Experiment II has not resulted in clear findings concerning either VEP latency or amplitude changes under conditions of backward masking. A major difference in the procedure used in Experiment II, from the procedure used earlier (Andreassi et. al., 1976) was the SOA between target and mask. In the earlier study, it was 60 msec, while in the present one it was 80 msec. This 80 msec SOA may have been sufficient to produce backward masking under Condition B of the present study, but may have been too long a delay to affect the VEP latency or amplitude in a consistent manner. Timing between target and mask appears to be a critical factor. It was for this reason that another study was designed to test the effects of amount of contour interaction between target and mask stimuli upon masking and the VEP in situations where the SOA is reduced to 60 msec rather than the 80 msec used in the present experiment. This latter experiment is still in progress.

Experiment III: Backward Masking of a Target By Its Complement, and Associated VEP

The introduction to Experiment II indicates that a variety of backward visual masking paradigms have led to alterations of the VEP. In Parts A and B of Experiment III, we will explore the effects of presenting a "complement" of a target upon visual perception and the VEP. The visual backward masking paradigm will be used in which the mask (complement) follows the target. A definition of what we mean by a "complement" is in order. In the context of our computer-generated displays, a "grid" consists of a 5 X 7 array of light points (See Figure 1). A letter "Y", for example, can be produced by illuminating nine of these points of light. This leaves 26 points which are not illuminated. These 26 points can later be activated as a "complement" of the "Y", producing a situation where the letter "Y" is "surrounded" by its complement, which appears shortly after it, in the typical backward masking paradigm. In Part A of this experiment, we designed a situation in which the complement would follow the "Y" by two different ISIs to determine the perceptual and VEP effects.

Part A: Backward Masking and VEP: Single Complement

METHOD

Subjects: The subjects were five males and one female associated with Baruch College of the City University of New York. None had visual defects other than myopia (corrected to at least 20/25).

Apparatus and Procedure: The apparatus and procedure for obtaining the VEP was the same as that used in Experiments I and II. The stimuli were displayed on a VR-14 Display CRT (Digital Equipment Corp.) which was mounted at the subject's eye level outside the chamber at a distance of 99 cm (39 inches) from the subject's nasion. The VR-14 CRT was controlled by the PDP-8/E digital computer which was programmed to deliver stimuli at specific times and locations upon the CRT. There were three conditions:

Condition A - One Y appearing on the screen for 40 msec. (ON 40, OFF 1500)

Condition B - One Y appearing on the screen for 40 msec. followed by a complement 20 msec. later which was on the screen for 40 msec. (ON 40, OFF 20, ON 40, OFF 1500)

Condition C - One Y appearing on the screen for 40 msec. followed by a complement 60 msec. later which was on the screen for 40 msec. (ON 40, OFF 60, ON 40, OFF 1500)

In every instance there was always 1500 msec. between each set of stimuli. For example, one Y and one complement were presented in rapid succession, followed by a pause of 1500 msec. (1.5 sec.) before the next set of one Y and one complement. The letter Y was formed by nine points of light yielding 1.11 mL for one Y at a distance of 2.54 cm (measured by Tektronix J16 Digital Photometer). The complement of the Y yielded a luminance of 3.33 mL.

The stimuli were .95 cm (3/8 inch) high and .95 cm wide and at a distance of 99 cm (39 inches) produced a visual angle at the eye of 33 minutes of arc. The stimuli appeared in locations at the center of the 17.78 cm (7 inches) high by 22.86 cm (9 inches) wide CRT screen. A small luminous fixation point .32 cm (1/8") in diameter, placed 1.27 cm above the center of the stimulus location was used to give subjects a place upon which to focus their eyes between presentations. The subjects were familiarized with the various displays, prior to data collection, via 10 sample presentations of each condition. The conditions were counterbalanced across the six subjects and data collection involved the presentation of each condition two times for each subject in one session.

RESULTS

The first result examined concerned the perceptual reports. The questions asked of each subject yielded the following information:

Condition A - All six subjects saw one Y (one Y presented)

Condition B - All six subjects saw one complement (one Y and one complement presented - masking of Y occurred)

Condition C - All six subjects saw one Y and one complement (one Y and one complement presented - no masking occurred)

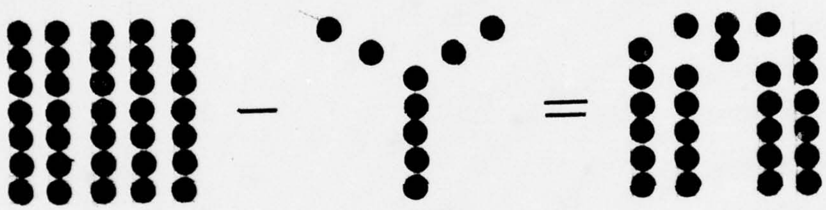

Figure 1 - Manner of constructing a Y and its complement from a basic grid array of 5 X 7 points of light. Nine of the grid elements are used to form the Y; when the nine points are subtracted from the original 35, a complement composed of 26 points results. The complement was used as a mask stimulus which followed the target Y in Parts A and B of Experiment III.

Thus, all individuals saw what was expected in all conditions. Condition B shows complete masking of the Y by the complement. The perceptual reports of stimuli in Condition C indicated that no masking occurred since all subjects saw both the Y and the complement. The data were analyzed with respect to both latencies and amplitudes of the VEP as in the prior experiments.

Table 1 shows the mean amplitude (μV) for major VEP components under the three conditions. The information in Table 1 indicates that Condition C consistently produced the highest VEP amplitudes of the three conditions used. Condition

Table 1

Mean Amplitude (μV) for Major VEP Components for Conditions A, B C
N = 6

VEP Component	Conditions A	B	C
N1	-	3.42	3.82
P1	3.65	3.94	4.35
N2	4.83	4.67	5.54
P2	9.17	9.92	9.96
N3	-	-	8.80
P3	-	-	4.65

C produced extra response components labeled N3 and P3. Inconsistencies characterize Condition B when it is compared to Condition A with respect to amplitudes of P1, N2 and P2. The information in Table 1 is depicted in Figure 2.

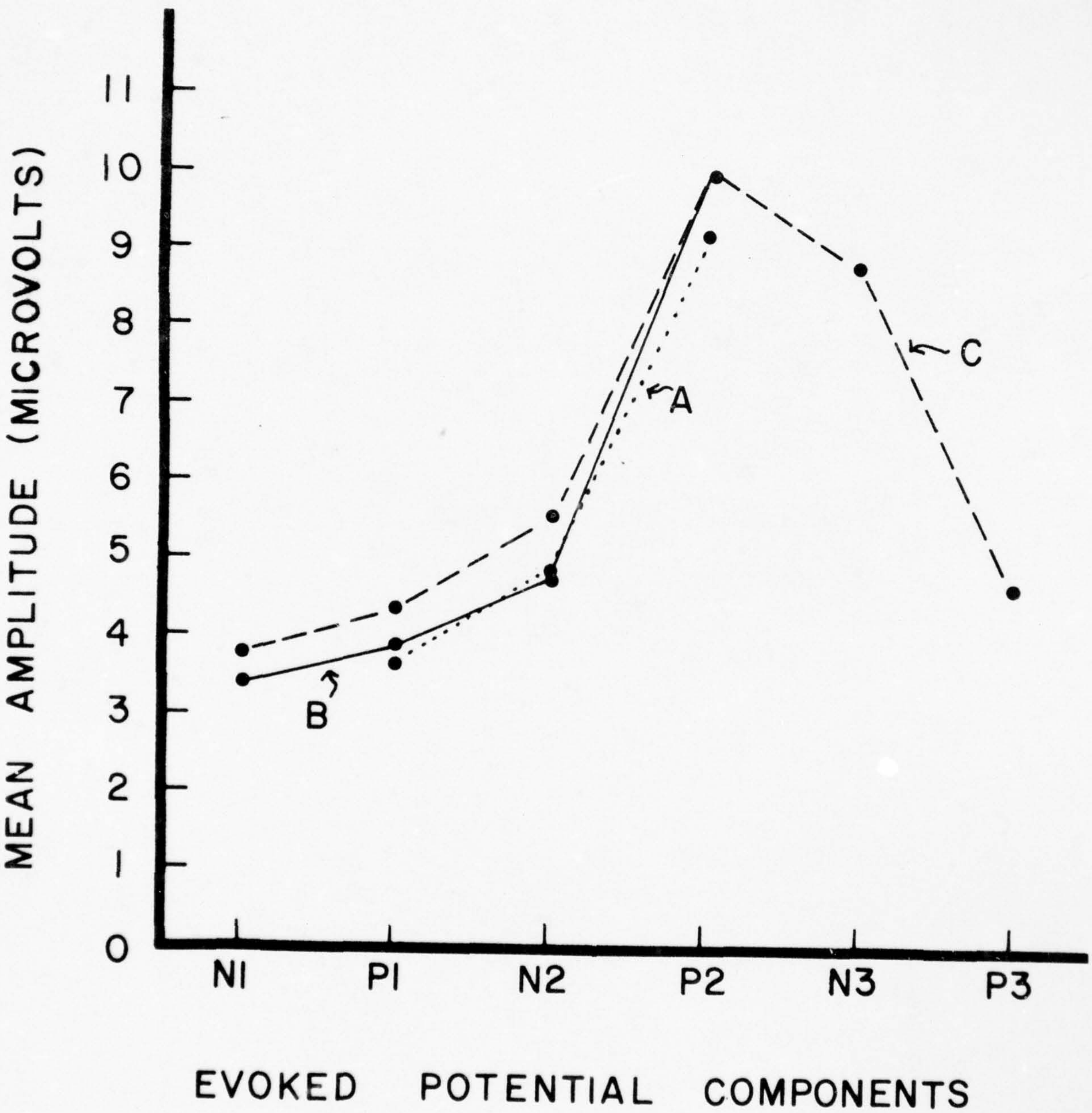

Figure 2 - Mean amplitude (μv) of major VEP components (6 Ss) under Conditions A, B and C.

Table 2 shows the mean latencies (msec.) for the major VEP components under the three conditions. The latencies for the three conditions do not show much variation except for the delayed P1 component for Condition B.

Table 2

Mean Latency (Msec.) For Major VEP Components for Conditions A, B, C
N = 6

VEP Components	Conditions A	B	C
N1	-	110	100
P1	130	149	125
N2	176	172	171
P2	241	240	240
N3	-	-	310
P3	-	-	350

The latency data are plotted in Figure 3. In Figure 3 the latency similarity between the three conditions can be clearly visualized. The amplitude and latency data for the major VEP components of N2 and P2 were subjected to t-tests for correlated data, 2-tailed criterion, with five degrees of freedom. The following comparisons were made: A vs. B, A vs. C, and B vs. C. None of the t-test comparisons resulted in significance ($p > .05$, 5 df.).

The VEP traces for one subject (P.G.) are presented in Figure 4. These traces are representative of the other subjects in terms of amplitude and latency results. The person whose VEPs are depicted in Figure 4 had a mean P2 amplitude of 14.25 microvolts under B, and 13.50 for both the A and C conditions.

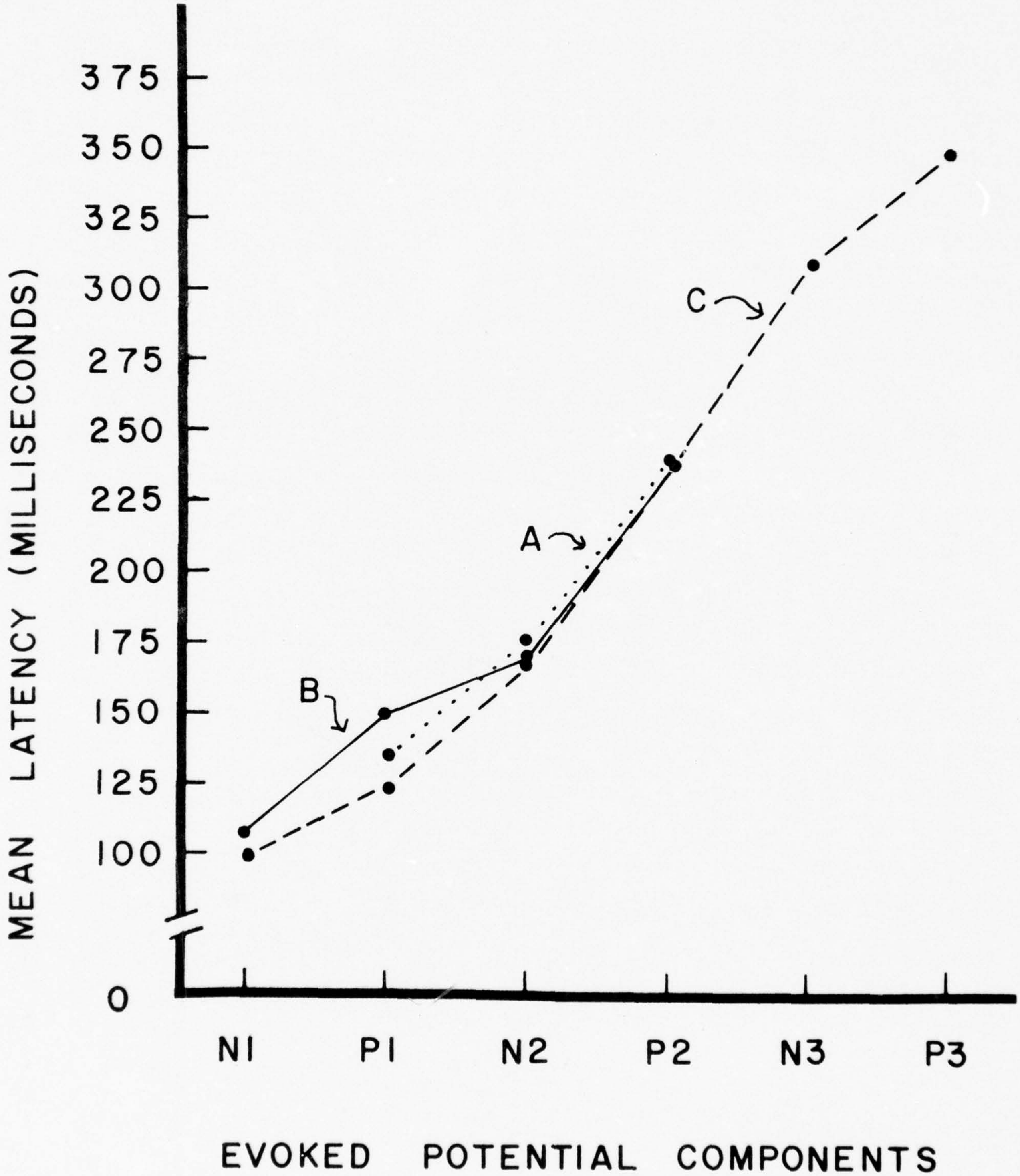

Figure 3 - Mean latencies (msec) of major VEP components (6 Ss) under Conditions A, B and C.

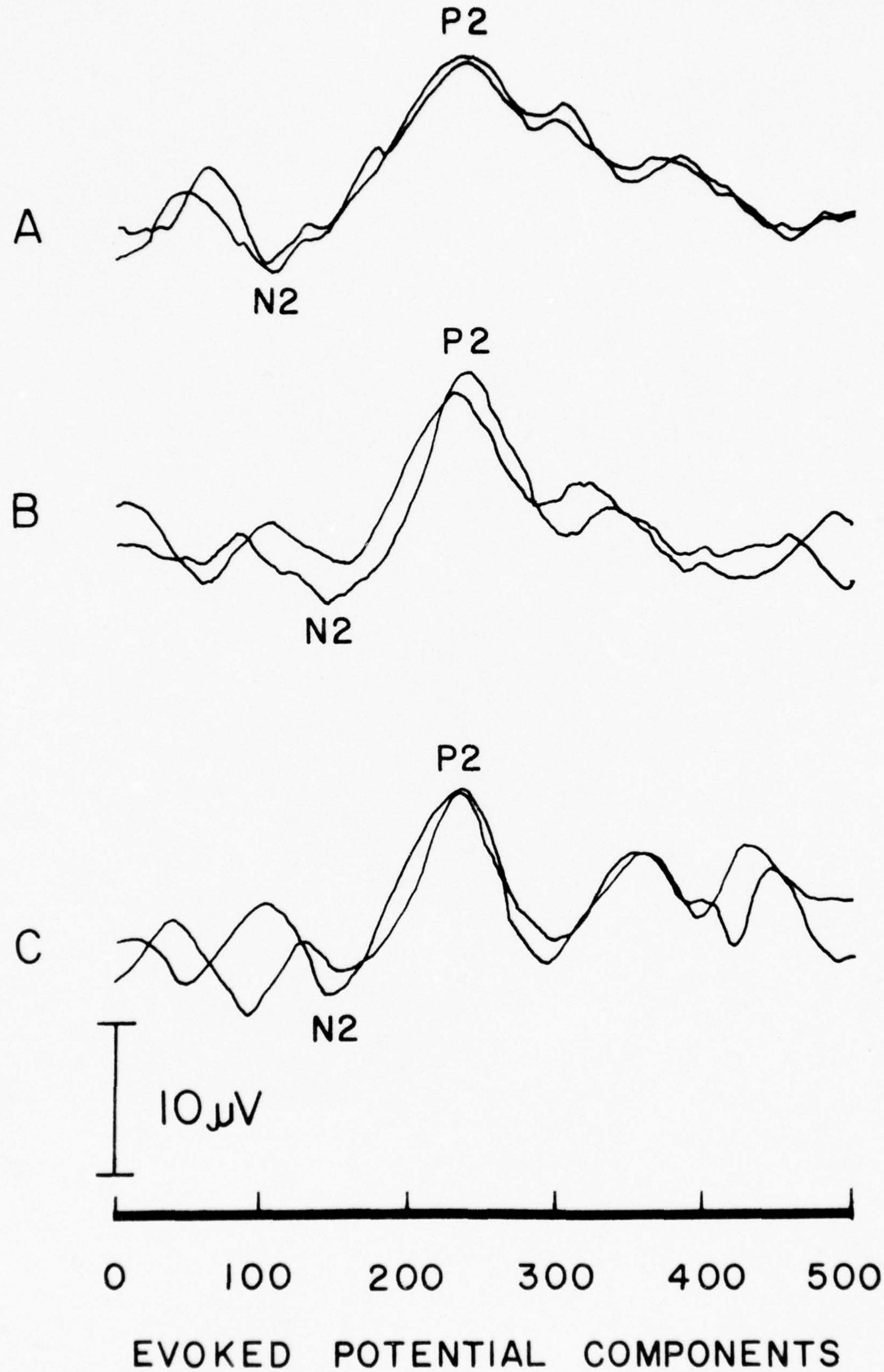

Figure 4 - Raw VEP traces for one subject (P.G.) under Conditions A, B and C. Each trace is based on 100 presentations. Negativity is downward.

DISCUSSION

The results indicate that under the stimulus conditions used, backward masking did occur. This finding stems from the perceptual reports obtained for Condition B, where all six subjects saw only the complement when a Y and a complement were presented. Under Condition C, all subjects saw and responded to the Y and the complement. This effect appears to be a function of the ISI in Condition C. That is, the 60 msec. between the end of the target and beginning of the mask allowed sufficient time for additional VEP components to occur as well as perception of the two stimuli presented in sequence.

Schiller and Chorover (1966) obtained metacontrast suppression using a disk and ring backward masking paradigm, but no alteration in the VEP. However, Vaughan and Silverstein (1968) reported VEP amplitude attenuation under metacontrast suppression for foveal presentation, but not for parafoveal stimuli. Vaughan and Silverstein suspect that the reason for the lack of VEP attenuation in the metacontrast experiment of Schiller and Chorover was the parafoveal stimulation used.

Andreassi et. al. (1974), in a masking paradigm using homogeneous stimuli, found a delay in the appearance of VEP components when the last three stimuli were of greater intensity than the first two stimuli. The greater the intensity difference, the greater was the delay in the VEP components. One may assume that from the results of the present experiment perhaps an intensity ratio larger than the one used in the present experiment (3:1) is necessary to produce a latency delay. Earlier studies (Andreassi et al., 1971) had shown that when the first two stimuli in a horizontal string of five were of equal intensity to the last three, no alteration in the VEP occurred.

Since the present study did not lead to any clearcut results, a follow-up experiment was conducted to determine whether a redesign of the stimulus situation would produce masking accompanied by changes in the VEP. In addition, each subject was tested in three sessions over a three day period instead of only one session.

Part B: Backward Masking and VEP: Multiple Complements

The major changes involved modifications in the number of stimuli used, and the timing of the stimulus presentation. More specifically, these changes were: (1) The use of three Y's and three complements; (2) the ON time and OFF time were set at 20 msec. each; (3) the collection of data took the form of a counterbalancing of the three conditions across six subjects for three days. This resulted in an increase in the number of VEP recordings obtained. The research questions asked were:

(1) Will backward masking be produced under the stimulus conditions of the present experiment?

(2) If backward masking does occur, will it be accompanied by changes in the VEP?

METHOD

Subjects: The subjects were three male and three female students associated with Baruch College of the City University of New York. None had any visual defects other than myopia corrected to 20/25.

Apparatus and Procedure: The apparatus and procedure were the same as in Experiment 1.

The three conditions were:

Condition A - Three Y's (ON 20 msec, OFF 1500 msec)

Condition B - Three Y's (ON 20 msec, OFF 20 msec., then three complements ON 20 msec., OFF 1500 msec)

Condition C - Three complements (ON 20 msec., OFF 1500 msec., but initiated at time 40 msec. as were the complements in A and B)

A single letter Y had a luminance of .37 mL at a distance of 2.54 cm. and a single complement had a luminance of 1.11 mL at a distance of 2.54 cm. The three together yielded luminance values of 1.11 mL and 3.33 mL for Y's and complements, respectively; the same totals as for the stimuli in Part A. For any given condition a set of three adjacent stimuli yielded a visual angle at the eye of 1 deg. 39 min.

RESULTS

The amplitude and latency data were obtained in the same manner as in the previous experiments. The perceptual reports indicated that backward masking did occur under Condition B. A summary of these reports are presented for the three conditions:

Condition A - All six subjects saw three Y's (three Y's presented)

Condition B - Five subjects reported seeing only the three complements, while one subject reported seeing three complements and one Y (three Y's and three complements presented)

Condition C - All six subjects reported seeing three complements (three complements presented)

To report the complement, subjects described various objects, such as seeing an arch, a black Y inside a circle, a curved box with a Y in it, and a box with the top two corners cut off.

Table 3 shows the mean amplitudes (μV) for major VEP components under the three conditions.

Table 3

Mean Amplitudes (μV) for Major VEP Components for Conditions A, B, C
N = 6

VEP Components	Conditions A	B	C
N1	3.57	2.96	3.13
P1	3.20	3.33	4.31
N2	5.40	4.96	5.43
P2	11.77	11.64	11.76

These data are depicted in Figure 5, which shows that there is not much variation in the amplitude data under the three

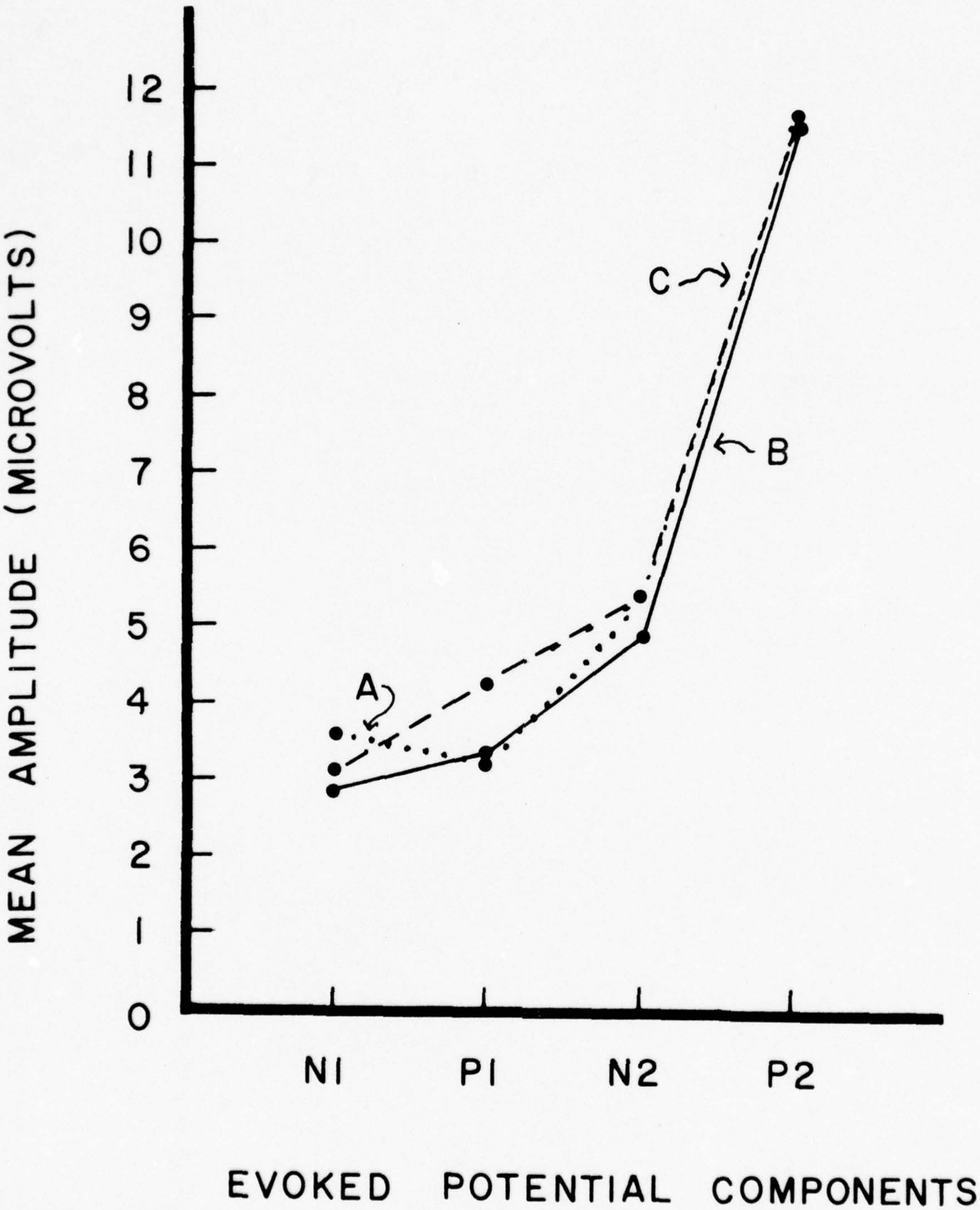

Figure 5 - Mean amplitude of the major VEP components (6 Ss) under Conditions A, B and C.

conditions. The mean latencies are given in Table 4. The

Table 4

Mean Latencies (msec.) for Major VEP
Components for Conditions A, B, C
N = 6

VEP Components	Conditions A	B	C
N1	88	100	115
P1	119	130	152
N2	150	159	190
P2	217	221	255

latency data reveal differences between conditions (see, also, Figure 6) for all VEP components (N1, P1, N2 and P2). The trends indicate that Condition A latencies are shorter than B, and B are shorter than C. The N2 and P2 latency differences were analyzed by t-test for correlated data and for N2: A vs. b ($t = 3.35$, $p < .05$, 5 df.); A vs. C ($t = 4.72$, $p < .01$, 5 df.); and B vs. C ($t = 4.60$, $p < .01$, 5 df.); while for P2 latencies A vs. B ($t = 1.52$, $p > .05$, 5 df.); A vs. C ($t = 17.34$, $p < .001$, 5 df.); and B vs. C ($t = 9.25$, $p < .001$, 5 df.). None of the N2 or P2 amplitude comparisons for any of the conditions were significant ($p > .05$, 5 df.). Figure 7 presents the superimposed VEP traces for one person (B.W.M.) in one experimental session. The mean N2 latencies for this subject were 146 msec. for Condition A, 158 msec. under B, and 177 msec. for C, a trend followed by the other five subjects.

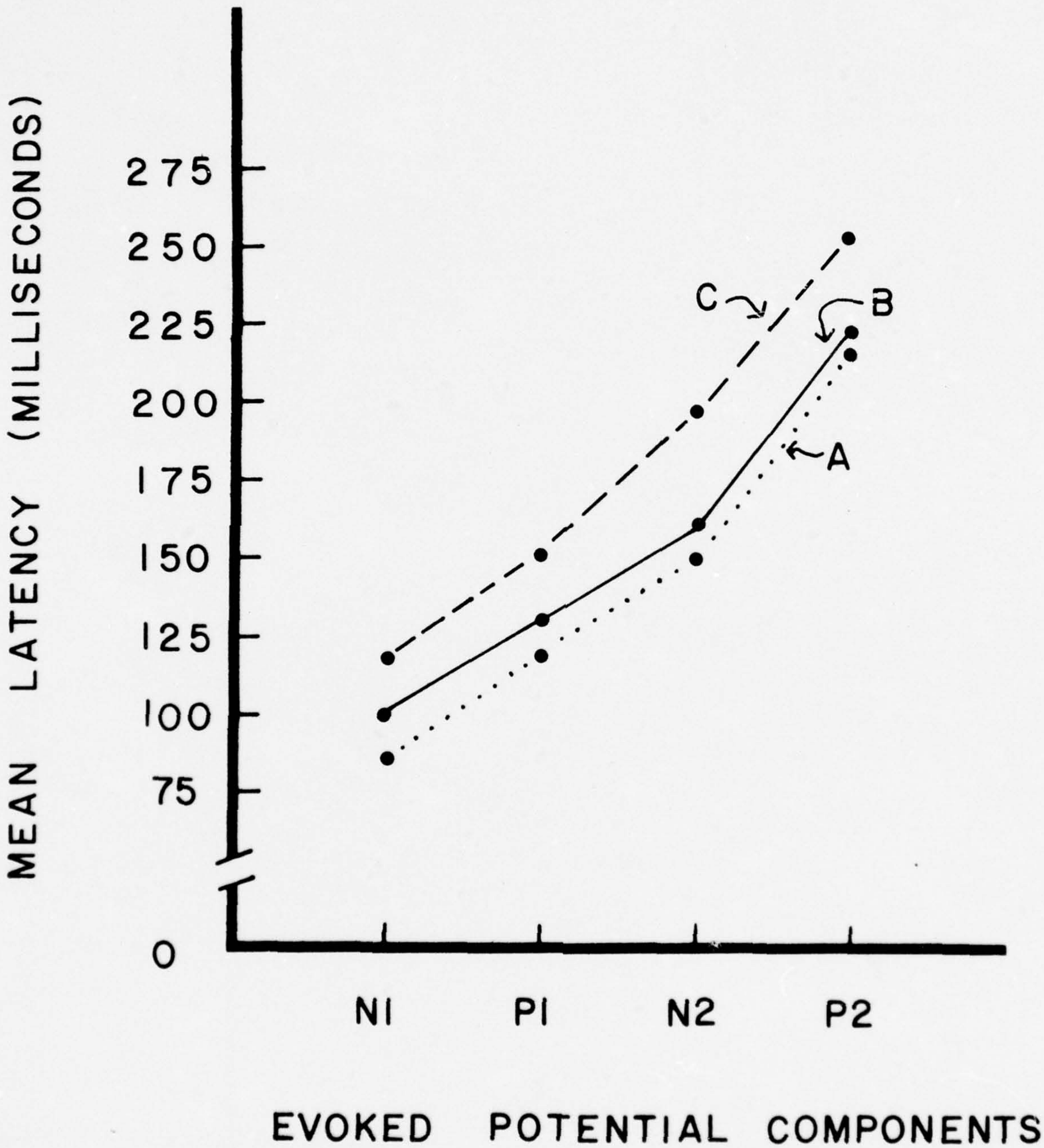

Figure 6 - Mean latency of major VEP components (6 Ss) under Conditions A, B and C.

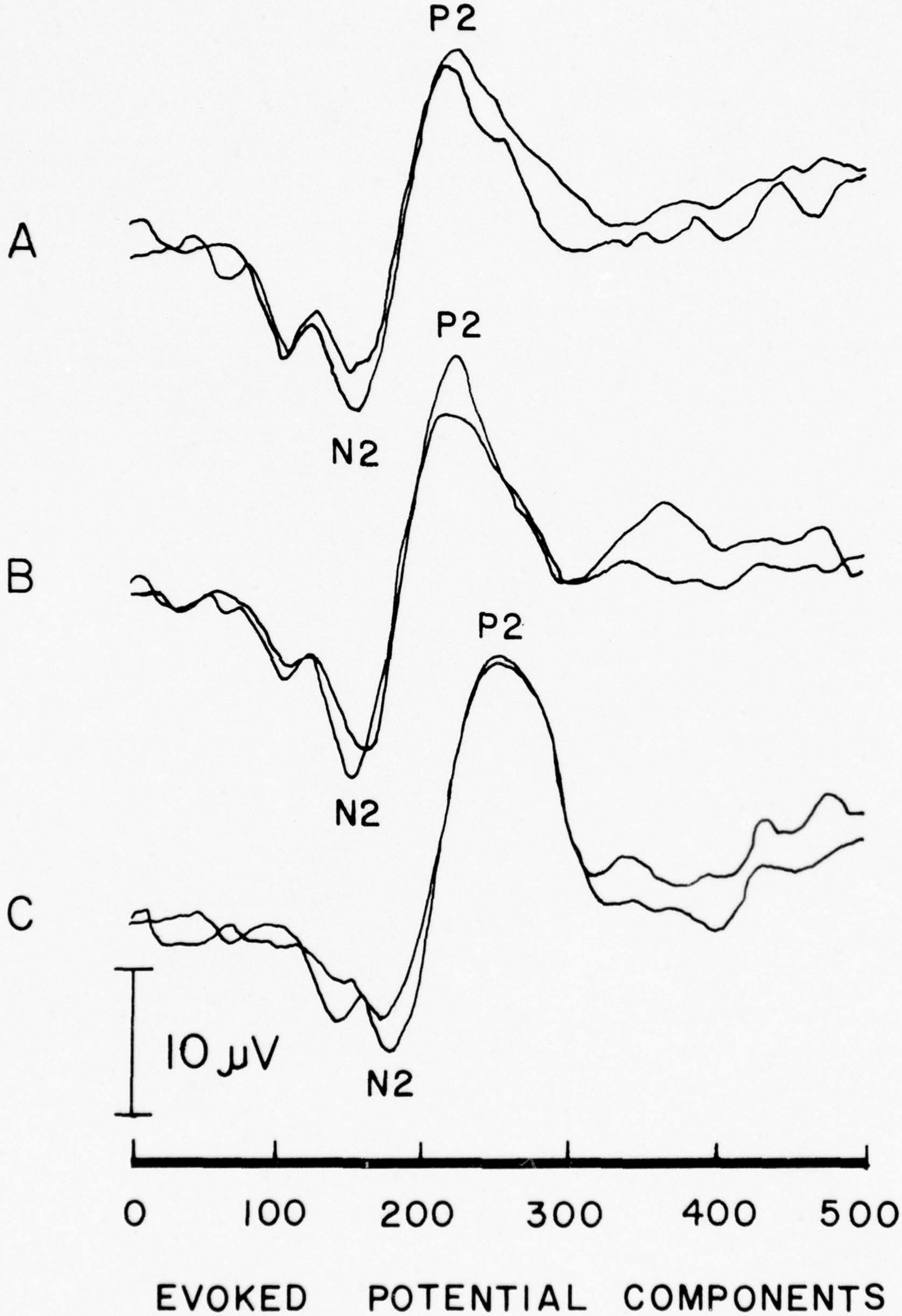

Figure 7 - Raw VEP traces for one subject (B.W.M.) under Conditions A, B and C. Each trace is based on 100 presentations. Negativity is downward.

DISCUSSION

The findings from Part B of Experiment II showed that perceptual masking was accompanied by latency changes in one component (N2) of the VEP. Previous studies by Andreassi et al. (1971) and Andreassi et al. (1974) found that when five single, sequential inputs of equal intensity are presented, the first two were not perceived. Further investigation revealed that if the last three stimuli were of greater intensity than the first two the perceptual suppression was accompanied by a delayed VEP to the first stimulus in the series. In addition, the greater the difference in the ratio between the first two stimuli and the last three, the longer the delay in the appearance of the VEP to the first stimulus. The explanatory mechanism for the findings of the present experiment and those of Andreassi et al. (1971, 1974) may be that the later appearing, more intense mask stimuli produce an inhibitory effect upon the excitation generated by the target stimuli, of sufficient magnitude to delay the VEP to the target. The results in Part B differed from Part A. Some factors contributing to this discrepancy may be: (1) the difference in the stimulus area; (2) "stimulus impact"; and (3) the amount of data collected in Part B. In Part A, a stimulus set consisted of one Y and one complement producing a visual angle at the eye of 33 minutes of arc. However, in Experiment II, the stimulus set consisted of three Y's and three complements producing a visual angle at the eye of 1 deg., 39 minutes of arc. The larger visual angle in Part B may have generated a larger area of excitation at the retina and visual cortex. In addition, the "stimulus impact" (because of greater area and number of stimuli) would be of higher magnitude in Part B than in Part A. (It should also be noted that the intensity ratio between the target and mask was constant at 3:1 in Parts A and B.) In Part A, two VEP recordings were obtained for each condition, and in Part B, six VEP recordings were obtained over three days resulting in a greater amount of data, and perhaps more reliability of the findings in B compared to A.

The findings in the present experiment may also be explained in terms of an interruption theory of backward masking as explained by Kahneman (1968). The processing of the first set of stimuli (three Y's) required a certain amount of physiological time, and this processing was interrupted by the presentation of the three complements during this processing. Previous experiments by Donchin and Lindsley (1965) and Fehmi et al. (1969) had indicated that the VEP occurred to the target rather than the mask. However, in these studies, the mask was of much greater intensity that the target (from 100 to 10,000 times greater) while in the present experiment the intensity ratio was only 3:1.

Another aspect of Part B deserving mention is that the VEP to the complement presented alone (Condition C) was very similar to the Y plus complement condition (B). The only difference was the temporal offset produced by the fact that the complement in C appeared 40 msec. later in time than the Y in B. Thus, while the results of Part B are suggestive, they are not conclusive and the complement paradigm will require further study.

Experiment IV: Effects of Configuration and Meaning upon Masking and the VEP

Prior backward masking experiments have shown that a target is most likely to be masked when the mask is similar to the target and borders the target contour (Werner, 1935; Mayzner and Tresselt, 1970; Andreassi, DeSimone and Mellers, 1976). Alpern's (1953) studies showed that masking is maximal when the borders of the mask and target are contiguous since masking dropped off sharply as spatial separation increased. Werner (1935) believed that what he termed metacontrast suggested something about the timing necesssary for perceiving contours by the visual system. If a second stimulus (mask) was presented soon enough after a first (mask) it could interfere with the contour development of the first and prevent its perception by the observer. The argument that some kind of lateral inhibition effect must be involved in backward masking has been presented by Mayzner and Tresselt (1970); Andreassi et al. (1971); Lefton (1972) and Andreassi et al. (1976).

It has been reported that when a target and mask differed sufficiently in configuration backward masking did not occur (Mayzner and Tresselt, 1970; Andreassi et al. 1976). In addition, while the VEP to a target stimulus was attenuated in amplitude with backward masking the VEP was not affected when configuration differences allowed perception of the target stimulus. The present experiment was designed to test the effects of three stimulus conditions upon the VEP: a blank field, a meaningless word and a meaningful word. One condition was designed to produce a blank central field by backward masking of a target stimulus (Condition A). A second condition was one in which the target was not masked and the subject perceived a three letter word (Condition B). The third condition allowed a nonsense target word, of three letters, to be perceived by the subjects (Condition C). The purpose was to determine whether there would be a hierarchy of VEP response to the three stimulus situations; that is, would the smallest VEP be produced under masking? Would the next smallest be produced with a meaningless stimulus and would the largest VEP result when the meaningful word was perceived? Further, would there be a differential result for the right and left hemispheres? That is, would the hierarchy be demonstrated for the left hemisphere because it is the one which controls the perception of speech and verbal language stimuli, as opposed to the right hemisphere which is dominant for spatial and non-analytical functions? It has been ascertained that 98% of the population has speech and language functions localized in the left hemisphere (Noback and Demarest, 1975). The affective value of stimuli has been found to influence the size of the VEP. Lifshitz (1966) used color photographs which were neutral, offensive or erotic for normal males and found VEPs larger for erotic than for other stimuli. However, he did not control for color or possible pupillary changes due to interest value of stimuli.

Begleiter and Platz (1969) also reported VEP differences to words of different affective content. They found VEPs to have greatest amplitudes with "taboo" words, the next highest for neutral words and lowest amplitudes for a blank flash field. While our stimuli were not designed to have strong affective value they do differ in meaningfulness.

METHOD

Subjects - The subjects were three males and three females associated with Baruch College. None had visual defects other than myopia (corrected to at least 20/25).

Apparatus and Procedure - The apparatus was the same as that used in prior experiments to obtain the visual evoked potential. The present procedure involved measuring from O_1 and O_2 (10-20 International System) during presentations of stimuli. The stimuli were presented to subjects on a VR-14 CRT display mounted outside the window of an IAC Chamber. The stimuli appeared at eye level at a distance of 137 cm (54 inches) from the subject's nasion. The three stimulus conditions were:

A. Three adjacent grids (one cm square) appeared on the screen for 20 msec (target) followed by eight identical grids, 40 msec later. The eight masking grids spatially surrounded the first three: three above, three below and one on either side.

B. The letters BAR appeared on the screen for 20 msec followed by the eight grids 40 msec later.

C. The letters ABR were presented for 20 msec, followed by the eight grids 40 msec later. In all conditions the eight grids were also presented for 20 msec, then followed by a blank screen for 1000 msec before the next stimulus sequence.

All stimuli presented first will be referred to as the Target. The 3 cm Target array produced a visual angle of 1 deg. 6 min of arc at the eye. The 5 cm wide mask produced a visual angle of 2 deg. 6 min. of arc. The Target intensity was 5.5 mL in Condition A and 3.4 mL in B and C. The mask intensity was constant at 5.5 mL for all three conditions. A small round fixation point .32 cm (1/8th in.) was placed 1.27 cm (1/2 in.) above the center of the stimuli. This fixation provided a cue as to the locus of each stimulus presentation. Instructions to subjects asked them to focus upon the fixation point between and prior to the start of presentations. All subjects were screened prior to participation. They were required to meet the criterion of complete masking of the target grid in Condition A and clear perception of the three letters used in Conditions B and C. All subjects screened in this manner met these criteria, this in spite of the fact that the mask was more intense than the target stimuli in B and C. The subjects were asked to draw a diagram of what they saw, as well as to describe the stimuli.

The three conditions were completely counterbalanced across the six subjects, through a use of a Latin Square design, over a period of three days. Each subject was presented with all conditions six times during the course of three experimental sessions. Thus, a total of 18 VEP traces from O_1 and 18 from O_2 were obtained. Each trace was based on the summed response to 100 stimulus presentations.

RESULTS

The subjective reports indicated that each subject consistently saw the same thing throughout the experimental trials. That is, the three grid Target was masked, and they clearly saw the three letters in the other two conditions. The amplitude and latency measures were taken in a similar manner as in the earlier experiments reported upon here. In Table 1 the

TABLE 1

Mean Amplitude (Microvolts) for
Major VEP Components Under
Conditions A, B, C.

(N = 6)

VEP Components	O_1			O_2			Placement
	A	B	C	A	B	C	Conditions
N1	2.13	2.0	2.3	2.60	1.75	3.05	
P1	4.34	4.03	4.03	5.18	3.80	4.28	
N2	4.25	4.83	4.90	4.90	5.00	4.78	
P2	6.03	7.18	6.87	6.32	6.90	6.88	

mean amplitudes of the major VEP components are shown for Conditions A, B and C for O_1 and O_2. The latency data are presented in Table 2. The data from Table 1 are plotted as Figure 1 and those from Table 2 are plotted as Figure 2.

Table 2

Mean Latency (Milliseconds) for
Major VEP Components Under
Conditions A, B, C.

(N = 6)

VEP Components	O_1 A	O_1 B	O_1 C	O_2 A	O_2 B	O_2 C
						Placement Conditions
N1	85	115	102	92	114	110
P1	140	136	134	142	135	139
N2	176	164	164	181	171	170
P2	239	235	233	240	231	234

The data in Figure 1 indicate a trend in which VEP amplitudes were smaller for Condition A than B or C. Although in the predicted direction these amplitude differences are not significant as revealed by t-tests for correlated data ($p > .05$, 5 df). The differences between the O_1 and O_2 locations are also not significant as indicated by similar tests ($p > .05$, 5 df).

The latency data plotted in Figure 2 indicate a tendency for Condition A to produce lsightly longer latencies than either B or C. However, these latency differences were not significant according to t-tests for correlated data ($p > .05$, 5 df). The same non-significance applied when the latencies for the O_1 vs. O_2 locations were compared.

DISCUSSION

The stimuli used in the three conditions of the present experiment did not result in differential VEPs for either conditions or left and right hemispheric comparisons. The perceptual results were in the expected direction since the grid targets were masked by the grid masks and the letter patterns were clearly perceived whether the letters made up the meaningful word, BAR, or the meaningless, ABR. Perhaps VEP differences did not occur because the stimuli used were rather mild and may not have produced much of a perceptual impact on the subjects in this experiment. Compared to the affective stimuli used by Lifshitz (1966) and Begleiter and Platz (1969) the stimuli used in the present study were apparently not strong in an affective sense. Another possible reason for the lack of differences may have been the locations selected to study the evoked potential. Perhaps parietal or frontal leads would have yielded greater differences than the occipital areas examined since they might be more likely to reflect associative rather than visual responses.

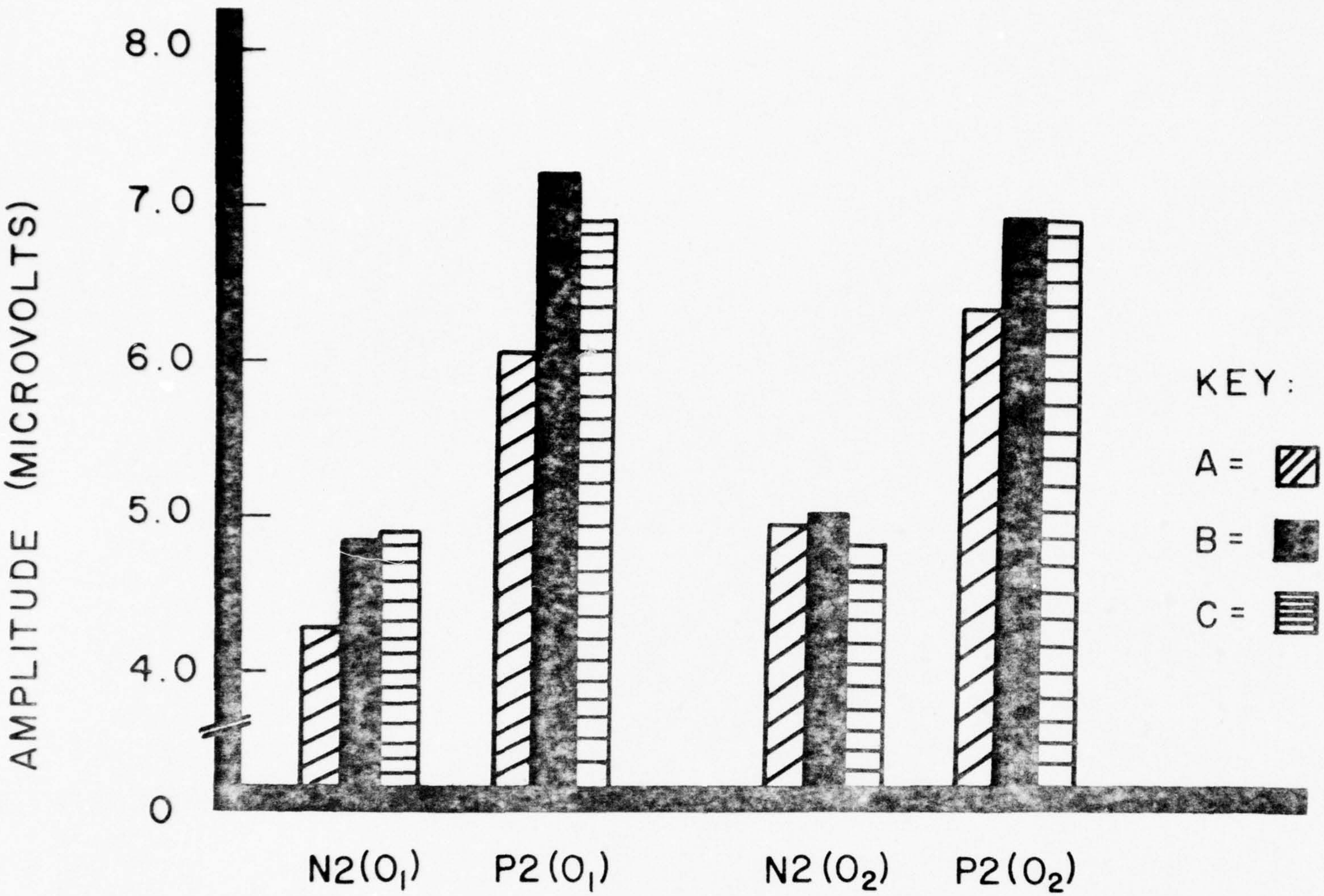

Figure 1. VEP COMPONENTS (SCALP LOCATIONS)

Amplitudes of N2 and P2 VEP Components for Conditions A, B and C. Locations O_1 and O_2.

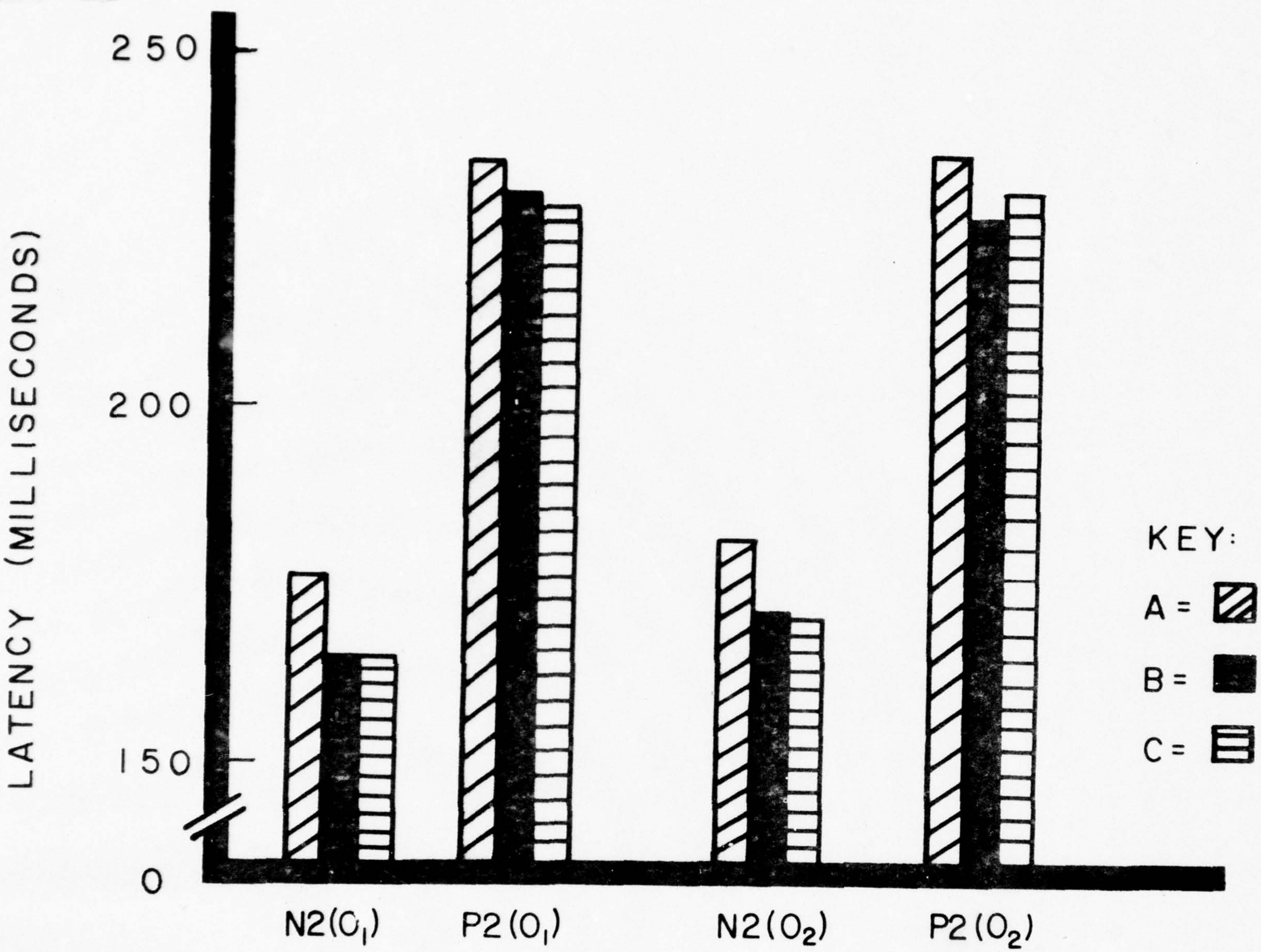

Figure 2. VEP COMPONENTS (SCALP LOCATIONS)

Latencies of N2 and P2 VEP Components for Conditions A, B and C. Locations O_1 and O_2.

Experiment V: Evoked Potential Amplitude Reduction Related to Extent of Visual Masking

The ability of the second of two successively presented visual stimuli to reduce the apparent brightness of the first is well documented (Stigler, 1910; Werner, 1935). This effect, called metacontrast, is produced when two equally-intense visual stimuli, having adjacent contours, are presented in rapid sequence. A typical paradigm for obtaining this effect involves the presentation of a solid black disc for a brief period (e.g.,5 msec) followed after an interval of 40 msec by a surrounding ring of equal area, intensity and duration, also presented for 5 msec. Schiller (1969) has referred to meta-contract as visual masking involving contour interaction as distinguished from a situation where no contour interaction occurs, as when a large, intense patch of light follows a small relatively dim light flash (Donchin, Wicke and Lindsley, 1963; Donchin and Lindsley, 1965). In backward visual masking studies the first stimulus is referred to as the target and the second as the mask.

In our present experiment we have obtained evidence that the extent of contour interaction was related to extent of target masking and visual evoked potential (VEP) amplitude reduction. The masks and targets were identical in luminance. Earlier studies of backward masking, in which VEPs were recorded with targets and masks of the same luminant intensity, were conducted by Schiller and Chorover (1966) and Vaughan and Silverstein (1968). It had previously been established that VEP changes occurred, i.e., lowered amplitudes and longer latencies, when the physical intensity of a visual stimulus was decreased (Tepas and Armington, 1962; Vaughan and Hull, 1965). Schiller and Chorover reported no VEP changes under metacontrast and concluded that the VEP does not necessarily reflect changes in subjective brightness. However, Vaughan and Silverstein found VEP amplitudes to be attenuated during metacontrast suppression when stimuli were foveal, but not when they were presented parafoveally. They suggested that the failure of Schiller and Chorover to obtain VEP changes was due to the parafoveal stimulus conditions used in their experiment. The amplitude decrease found by Vaughan and Silverstein occurred to the positive VEP component appearing about 200 msec after the first stimulus.

Recent studies of visual masking and their VEP correlates conform to the pattern masking situation in which the target and mask may both be letters or patterns, which were superimposed or adjacent to each other, with some of their contours in a contiguous relationship. For example, in a recent study VEPs to two simultaneously presented stimuli were reduced in amplitude when these targets were followed by three simultaneous, adjacent, stimuli (Andreassi, De Simone and Mellers, 1976). All of these stimuli were similar in configuration and the degree of target-mask contour interaction was never greater than 50%. When later stimuli differed in shape from earlier ones, masking was not produced and VEP amplitude decreases did not occur.

The question to be addressed in this experiment concerns the effects of increasing amounts of target-mask contour interaction upon perception of the target and the amplitude of the VEP. To answer this question an experiment was designed in which a single grid stimulus was followed by either one, two, three or four grid stimuli, in adjacent locations. Thus, the amount of target mask interaction was 0%, 25%, 50%, 75%, and 100% (See Figure 1). There were six stimulus conditions in all, two of them involved 50% contour interaction. Figure 1 is a schematic representation of the six experimental conditions.

The basic stimulus was a 5 x 7 square matrix (grid) consisting of 35 yellow-green points of light. Stimuli were presented on a VR-14 CRT display (Digital Equipment Corporation) mounted at the subject's eye level outside an IAC chamber window. The VR-14 was under program control of a PDP-8E digital computer. The CRT electronics are such that the total luminous energy appearing at any one time upon the screen is constant. This energy is equally distributed among simultaneously presented stimuli. Thus, a single grid produced an intensity of 5.50 mL, when measured at a distance of 2.54 cm from the CRT screen surface with a Tektronix J-16 digital photometer (with the display intensity control set to maximum), while 2 grids each produced an intensity of 2.75 mL. The

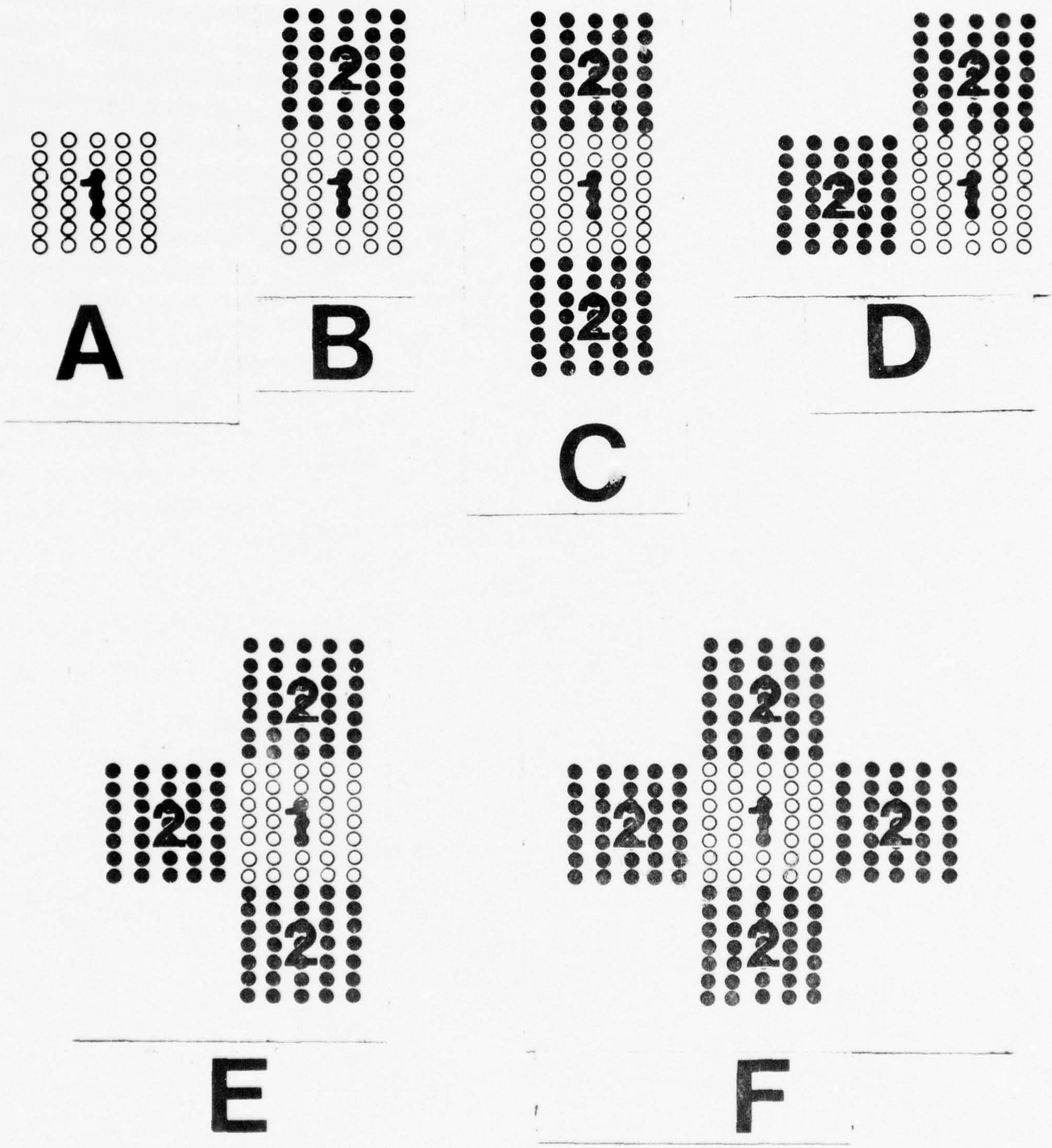

Figure 1 - Schematic of spatial and temporal arrangement of stimuli as they appeared on CRT screen under the various conditions of this experiment. Numbers merely indicate order of presentation, of target stimuli (1) and masks (2), and did not appear as part of the display. The total luminous energy of the target and mask was the same (5.50 mL).

VR-14 CRT screen used is equipped with a special phosphor which enables an extremely fast stimulus decay time (50 microseconds). The subjects faced a stimulus display 153 cm away and were instructed to fixate binocularly upon a small (3cm) dim (.001 mL) red neon light source located 6 mm above the center of the screen. The grids numbered "1" appeared first and those numbered "2" appeared 40 msec after the first disappeared. All stimuli were on a CRT screen for 20 msec. There were always 1000 msec between the end of each stimulus and the beginning of a new set. The single grid was .95 cm square and produced a visual angle at the eye of .35 deg. at the viewing distance used. An array of three adjacent grids (the greatest extent used) produced a visual angle of 1.05 deg. Thus, the stimuli were presented foveally since foveal extent is usually estimated at between 2.0 deg. and 2.5 deg. of visual angle (Ruch, 1965).

The subjects were three males and three females. None had known neurological or visual defects other than myopia (corrected to at least 20/25). All were tested in six experimental sessions, spread out over six days, at approximately the same time of day. The six conditions were counterbalanced across days and subjects, in a Latin-Square design. At the first experimental session subjects were shown each condition 10 times. After each set of sample trials they were asked to draw what they observed and to indicate the number of separate items detected for a given condition.

Further testing was continued only if subjects evidenced complete visual masking of the initial stimulus in at least one of the conditions. None of the subjects screened in this manner failed to meet this criterion. The instructions to subjects during experimental trials asked them to silently count the number of presentations and to report the number of items seen in any single presentation at the termination of each condition.

The electroencephalogram (EEG) was recorded from over the occipital cortex (O_Z) with a single silver cup electrode referenced to a clip electrode on the subject's left ear lobe. Another clip electrode on the right ear lobe served as a ground. An additional active lead was placed just over the left eye brow to record vertical eye movement and eye blinks. A Beckman type RM dynograph recorder was used to record the EEG and a Mnemotron Computer of Average Transients allowed derivation of the averaged evoked potential. The EEG bandpass filter of the Offner was set at 0.5 to 32.0 hertz, and the gain at 4 μV/mm. A "start" signal from the 8E computer triggered the CAT to take EEG samples of 500 msec duration following the presentation of each stimulus to the subject. The summated VEP responses from the CAT were printed by a Hewlett-Packard X-Y Plotter. Also averaged and plotted at the end of each 100 trials was the electrooculogram, which was recorded on a separate channel of the Beckman in order to detect possible distortions of the VEP due to eye movement or eye blink. Continuous on-line monitoring of the EEG was accomplished with a Tektronix 502A oscilloscope.

The VEP data analysis was accomplished by computing the mean amplitudes (μV) and latencies (msec) of each subject's VEP trace for each condition. Each VEP trace was based upon 100 EEG samples. The most prominent VEP component was a positive wave which occurred at about 200 msec after the first stimulus was presented. The P2 amplitudes were measured by taking the N2-P2 distance which was then referred to a calibrated signal. The N2 component occurred at between 130 and 150 msec and the P2 at between 190 and 220 msec across conditions and subjects. The amplitude analyses were based on the peak-to-peak N2-P2 magnitudes. The latency analyses were based on the time of appearance of the P2 component of the VEP. The latency and amplitude data were each subjected to analysis of variance (ANOVA). A two-way (Subjects x Condition) fixed model (Winer, 1971) was used. A log transformation of all the raw latency and amplitude data was conducted to ensure that they would conform to the assumptions required by the ANOVA. The ANOVA for N2-P2 amplitude indicated that both main effects were significant: Subjects, $F(5/180) = 19.00$ ($p <$ .001) and Conditions, $F(5/180) = 22.00$ ($p < .001$). The Subjects x Conditions interaction was insignificant, F(25/180 = 1.00 ($p > .05$). The Newman-Keuls multiple comparison test (Winer, 1971) was used to further examine the amplitude differences under the different conditions. The Newman-Keuls results indicate that amplitudes under Condition B did not differ from A ($p > .05$) but were significantly higher than under D, C. E and F ($p < .01$) while Condition A produced amplitudes which were significantly higher than D and C ($p < .05$) and E and F ($p < .01$). Conditions D and C did not differ from each other significantly, while both D and C were greater than E ($p < .05$) and B ($p < .05$). Finally, Condition E produced higher VEP amplitudes than F ($p < .05$). This hierarchy of VEP amplitudes is depicted in Figure 2 which shows the mean amplitude of the N2-P2 component, across the six subjects, as a function of condition. The ANOVA for the latency measures failed to find significant F ratios for either the Conditions main effect, $F(5/180) = 2.00$ ($p > .05$) or the Subjects x Conditions interaction, $F(25/180) = .50$ ($p > .05$). The Subjects main effect was significant, $F(5/180 = 22.00$ ($p < .001$), but this effect is not of practical significance in an experiment such as the present one in which variation between subjects is expected.

ANOVA results indicate a relationship between the amount of contour interaction between the initial stimulus and later stimuli, and amplitude of the VEP. The one exception was the B vs. A comparison (this discrepancy will be discussed later). A Spearman rho was computed between rank in degree of contour interaction for a given condition and rank in N2-P2 amplitude. A coefficient of +.93 was found, $p < .05$, thus supporting the conclusion that a relationship exists between degree of target-mask contour interaction and VEP amplitude.

The subjective reports indicated that under Condition A the single grid was always detected and under F (100% bounding)

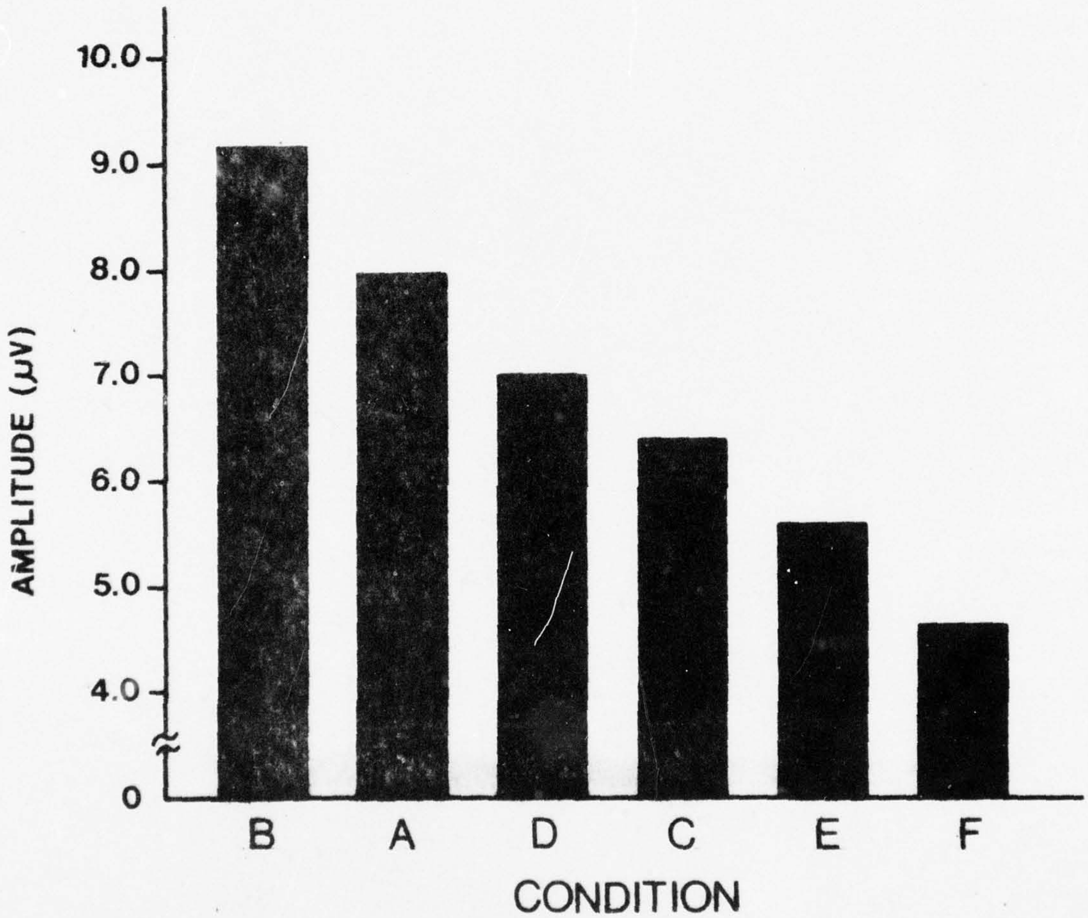

Figure 2 - Mean amplitude of P2 component of the VEP to target stimulus (for six subjects) under various conditions. The means and S.D.s are, respectively, B = 9.17, 2.80, A = 7.93, 2.33, D = 7.00, 3.15, C = 6.40, 2.00, E = 5.57, 2.15, and F = 4.65, 1.77.

complete masking of the initial stimulus consistently occurred. For Condition E (75% bounding) complete masking occurred for 5 of the 6 subjects. One of the subjects sometimes reported seeing "three squares and part of a fourth." Under Conditions C and D (50% bounding) four of the six subjects experienced complete masking of the first stimulus while two others frequently saw "two items plus fragments of a third." The subjective reports for Condition B (25% bounding) were interesting. Each subject experienced the same apparent motion effect in which the first grid seemed to move upward. Thus, subjects reported seeing only one grid. Perhaps the greater interest and attention produced by a stimulus which appeared to move resulted in the higher amplitude VEP when this condition was compared to Condition A. There is research evidence which indicates that greater attention to stimuli results in higher amplitude VEPs (Donchin and Cohen, 1967; Eason, Harter and White, 1969; Groves and Eason, 1969). Such a perceptual effect (i.e., apparent motion) would seem to remove the effect of contour interaction since the initial stimulus is seen to change its position in the visual field, and the overall perception is completely different from that produced under the other stimulus conditions in which the grids are perceived as stationary.

A possible explanation for the VEP amplitude changes which occurred as a function of degree of target-mask contour interaction is that varying amounts of excitatory-inhibitory activity between groups of neurons take place at the level of the visual cortex. Thus, we suggest that when a stimulus is presented to the visual system it results in excitation being produced at a given location in the visual cortex. When similar stimuli follow the initial one closely in time and space, adjacent areas of the visual cortex are stimulated, resulting in a reduction in response to the first stimulus. This inhibitory activity is not sufficient to eliminate the VEP completely, but enough to reduce it significantly, and, it would appear from the results of the present experiment, that the degree of VEP reduction might be related to the degree of bounding of the first stimulus by later ones. This excitatory-inhibitory hypothesis may explain the VEP attenuation and the visual masking observed in the present experiment, and the earlier ones of Vaughan and Silverstein (1968) and Andreassi, et al. (1976).

There are a number of lines of evidence which would seem to lend support to a cortical excitatory-inhibitory interaction hypothesis. For example, retinal projections are topographically organized at the level of the visual cortex, suggesting that patterns of light at the retina are translated into impulses at the visual cortex with elements of each pattern holding the same spatial relationship at the two areas (Ruch, 1965). Also, lateral inhibitory activities take place at the retinal level since impulses from a receptor are reduced in rate when neighboring receptors are simultaneously stimulated (Hartline, 1969). That lateral inhibitory effects can take place at the visual cortex is suggested by Hubel and Wiesel's studies in which they have identifed cortical cells of a simple, complex and hypercomplex variety which are involved in both inhibitory and excitatory activities. Finally, experiments to test the feasibility of visual cortical prostheses with blind patients provide some suggestive evidence that lateral inhibition can take place in the human brain (Brindley and Lewin, 1968; Dobelle and Mladejovsky, 1974). Electrically produced phosphenes, or sensations of light, seemed to interact when two adjacent portions of the visual cortex were stimulated (Dobelle, Mladejovsky and Girvin, 1974). Simultaneous or sequential stimulation of two adjacent areas resulted in reports by patients of one phosphene instead of two.

It is possible that the kinds of excitatory-inhibitory processes proposed at the visual cortical level also occur at other locations of the visual system such as the lateral geniculate nucleus or the visual radiations, but we lack recordings from these areas. The results from our study using surface electrodes indicate that increasing amounts of target-mask contour interaction results in increased amounts of VEP amplitude attenuation and subjective backward masking. Sample VEP traces for one subject (A.C.) are presented in Figure 3.

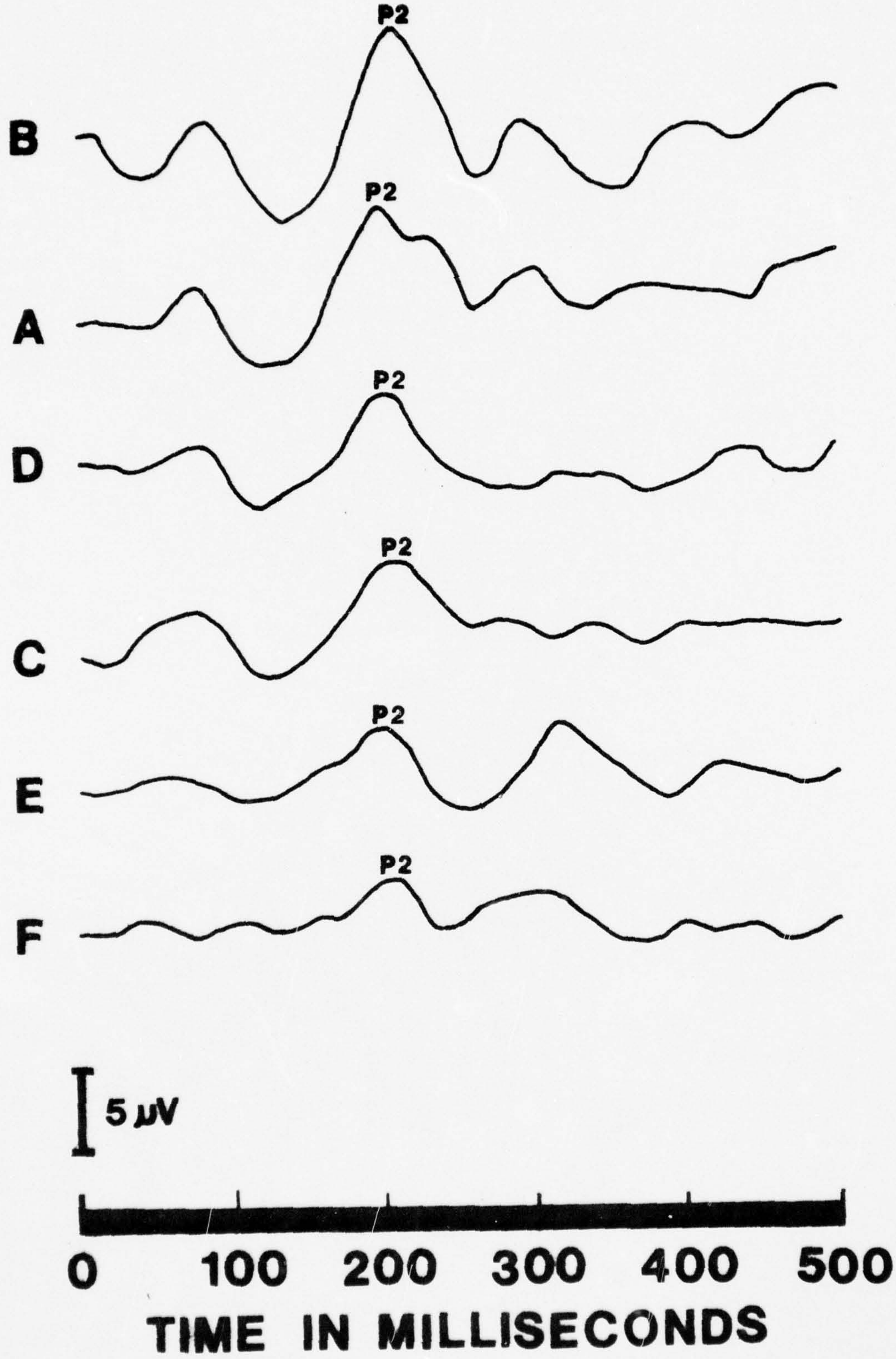

Figure 3 - VEPs for one subject (A.C.) under Conditions A, B, C, D, E and F. Negativity is downward.

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- Information Processing
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- Contour Interaction
- Computer Generated Displays
- Excitation - Inhibition
- Complementary Mask
- Mask Contiguity

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This is the fourth annual report to originate from the Psychophysiology Laboratory of the Psychology Department at Baruch College. The research completed over the last 12 months has included a number of studies concerned with evoked cortical potential correlates of stimulus processing in humans. The present report details the results of three

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) separate experiments, each consisting of two parts. One portion of Experiment I (Part A) was previously reported in the 1975 Annual Report. Part B of Experiment I is a follow-up conducted in an attempt to explain apparent male-female differences found in Part A, in which the visual evoked potential (VEP) of males was enhanced with induced muscle tension (IMT) but no consistent effect on VEPs of females was observed. In Part B, a new sample of 10 female subjects was tested with a reduced IMT level and VEP enhancement was observed.

In Experiment II, the effects of contiguity of target (initial) and mask (later) visual stimuli on backward masking and the VEP was examined. Backward masking was found to be affected by the contiguity of later-appearing grid stimuli, i.e., the closer the mask to the original target, the more likely was backward masking to occur. When masking stimuli were removed a short distance horizontally (Part A), masking still occurred in most instances. With the mask farther removed horizontally, masking did not occur (Part B). The VEPs did not differ reliably under the various conditions in either Parts A or B, possibly due to the less than optimal stimulus timing used. The effects of timing and degree of contiguity between target and mask will be examined in Experiment V.

Backward masking and the VEP, with new stimuli, was the focus of Experiment III. In Part A, a single character (letter Y) and its "complement" made up the target and mask stimuli, respectively. In Part A, the subjects experienced backward masking, but VEP changes did not occur. A more complex stimulus array was designed for Part B (three Ys and three complements) and under these conditions a VEP latency delay was observed under the masking as compared to the no masking condition. The VEP delay was discussed in relation to results of prior studies indicating VEP changes with backward masking.

Experiment IV examined VEPs, from left and right hemispheres, to meaningful and non-meaningful stimuli. No differences in either response amplitudes or latencies were found for meaningful and non-meaningful stimuli. It was suggested that perhaps parietal or frontal lead placements would have yielded greater differences since they might reflect associative rather than visual responses obtained from the occipital areas examined.

In Experiment V, the visual evoked potential (VEP) was measured under stimulus conditions in which the extent of visual masking varied. Increased amounts of contour interaction between target and mask stimuli resulted in stronger masking and progressively greater decreases in VEP amplitude. The results suggest possible excitatory-inhibitory neuron interactions at the visual cortex.

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